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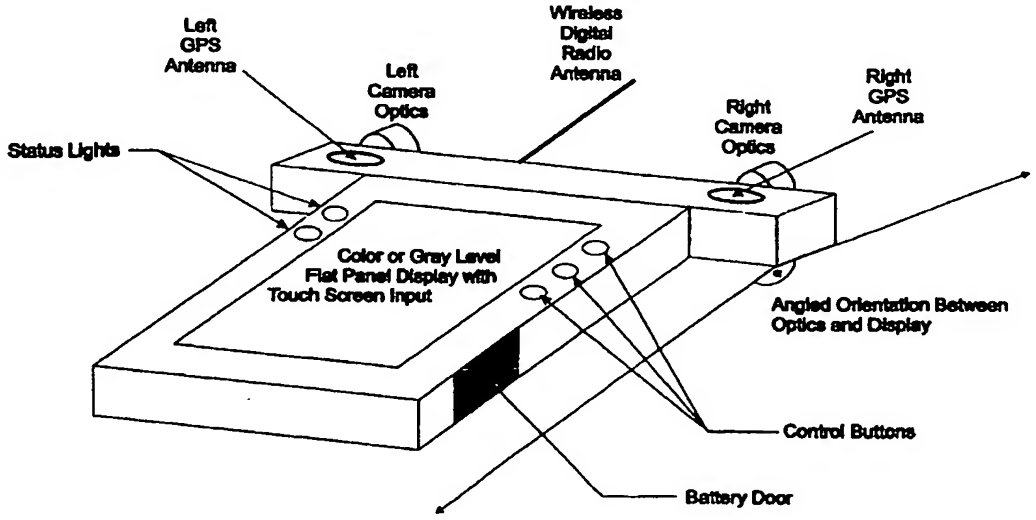

(57) Abstract

The subject invention provides devices and methods for efficiently and accurately gathering image and other field data using a handheld portable Geographic Data Manager (GDMs). The subject GDMs can utilize a combination of GPS antennas and receivers, digital compasses, inclinometers, gyroscopes, and digital cameras to gather, process, and/or store data which can provide the position and other geographic data and information pertaining to objects of study. The subject GDMs can have application to fields including environmental sampling, surveying, agriculture field data collection, property appraisal, law enforcement, and construction inspection.

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DESCRIPTION

HANDHELD PORTABLE DIGITAL GEOGRAPHIC DATA MANAGER

Cross-Reference to a Related Application

This application claims the benefit of the filing date of U.S. Provisional Application Serial No. 60/025,528 filed on September 6, 1996.

Background of the Invention

It is often necessary for insurance adjusters, geophysicists, construction workers, real estate developers, and others working in the field to gather and assimilate geographic, topographic, visual (*i.e.*, photographic), and other information about a site. These sites may be in locations which are remote and/or have no readily available access to computers or even power sources. Currently, there is no handheld portable device for gathering and processing such information.

Printed maps are available for viewing almost all features that have geographical locations. A limitation of printed maps is that a user must manually sort through the entire map in order to find the relevant geographical features. Electronic maps have recently become available to replace paper maps for some applications. A map database is stored in a memory storage device as a bit map or as vectors that point to a map character.

Many electronic location determination systems are available or have been proposed to provide electronic location information to a user equipped with a location determination receiver. Ground-based location determination systems are well known and include systems that were developed primarily for communications, such as cellular telephone, FM broadcast, and AM broadcast.

The Global Positioning System (GPS) is a global navigation system that enables the user to utilize signals broadcast from satellites in order to identify positions. GPS systems are well known and widely used to accurately locate specific positions. GPS systems, which utilize a network of satellites to identify locations on the ground, are

widely used in automotive and nautical navigation, construction, mining, and farming, as well as in a variety of other applications. See, for example, U.S. Patent No. 5,528,248 and PCT Application No. WO 95/05686. Other satellite positioning systems, such as the Global Orbiting Navigational System (GLONASS) are also known. Cartographers, utilities operators, wildlife managers, and others have used GPS technology in conjunction with Geographical Information Systems (GIS) to augment map making procedures and other field work, particularly in remote locations. In such applications, there has been an increasing use of computers to facilitate data storage and retrieval.

Personal Digital Assistant (PDA) is a generic name for a handheld personal computing device having a volume in the range of about 200 to 1200 cubic centimeters. PDAs can have as much computing power as some desktop personal computers and have been used in a wide variety of applications, including mapping.

Unfortunately, hardware and software hurdles have limited the ability to utilize multicomponent data gathering systems in the field. Connecting equipment such as a GPS, a two-way radio, and a handheld pen computer for use in the field poses a number of obstacles. Many wires and cables work fine on a desktop computer but not on a handheld device. The essence of the subject invention is the development of a rugged, fully-integrated, easy to use handheld multicomponent field data gathering system for gathering positional, image, and other data, and simultaneously processing this information.

Brief Summary of the Invention

The subject invention concerns methods and devices which aid in collecting and verifying planning and engineering field data. The devices of the subject invention, which can be handheld, portable, and digital, can be referred to as Geographic Data Managers (GDMs). The GDMs of the subject invention are designed to meet the needs of, for example, the construction and utility industries. The methods and devices of the subject invention are also applicable to other tasks such as environmental sampling, surveying, agricultural field data collection, property appraisal, law enforcement, and construction inspection. Specific applications include the gas, water, sewer, telephone,

and cable TV utilities; local, state, and federal government inspection agencies; and the insurance and transportation industries.

The GDMs of the subject invention comprise multiple components interfaced with, for example, a central processing unit (CPU). Preferably, these multiple components include at least one digital camera, at least one GPS receiving antenna, a GPS processing component, wireless radio communication capability, a digital compass with inclinometer, and user interaction capability. In a preferred embodiment of the subject invention, the GDM comprises at least two digital cameras which facilitate the determination of the distance from the GDM to an object. In a specific embodiment, a digital compass and an inclinometer of the GDM can enable the determination of the orientation of the camera so that the exact location of an object which appears in the images from the digital cameras can be readily determined.

The subject GDM can be utilized in applications where the determination of an object's location in two-dimensions is required, for example when the height of the object is not needed. In a specific embodiment, the subject GDM can be equipped with two GPS antennas and two cameras which can allow the determination of the object's location in two dimensions. In this embodiment, the two GPS antennas can be offset such that a heading and position of the GDM can be determined and the two digital cameras can provide the distance to the object, thus providing data needed to determine the object's location in two dimensions. Alternatively, a compass can provide the heading and two cameras can be used to provide the distance to the object from the location of the GDM. In another alternative embodiment, for example, if the direction of an object is known, an inclinometer and the two digital cameras can provide pitch and distance data which can be used to determine the height and distance to the object from the location of the GDM.

In a preferred embodiment, the subject GDM can comprise at least three GPS antennas and corresponding receivers, wherein the GPS antennas are in a plane. The receipt of the signal from one GPS satellite by all three of the GPS antennas can provide information with respect to heading, pitch, and roll of the GDM, as well as location. Accordingly, when this information is combined with the distance information determined from the images from the at least two cameras, the GDM can provide

information as to the exact location, in three dimensions, of the imaged object. Advantageously, the combination of the three GPS antennas can provide a more accurate determination of the GDM location due to receipt of the GPS signals by all three GPS antennas in a plane.

In another specific embodiment, the subject GDM can comprise at least one gyroscope, for example a laser gyroscope, which can provide data related to the GDM's heading, pitch and/or roll. Advantageously, a laser gyroscope can be less susceptible to confusion by metals than a compass, In addition, a gyroscope can be calibrated from data received from the GPS when the GDM's GPS antenna is moving.

In a further embodiment, the subject GDM can be incorporated with another structure, for example a vehicle. This other structure can incorporate at least one GPS antenna and a means for providing data to the GDM with respect to the GPS antenna's position relative to the GDM's camera(s). This embodiment can be useful when the GDM is used, for example near tall buildings, where the GPS satellite signals can bounce off and/or be blocked. The GDM can also have a means for mounting to the structure, for example a vehicle, such that its location relative to the structure is known. In a specific embodiment, the GPS antennas can be mounted on the structure in order to allow a greater distance between the antennas and, therefore more accurate distance determinations.

In a preferred embodiment of the subject invention, the GDM comprises capability for wireless transmission of data to a host computer at a remote location. The GDM of the subject invention can further comprise a touch screen controller and/or a voice controller. Preferably, the GDM of the subject invention further comprises a power source. This power source may be, for example, a battery pack and any necessary electrical components to modulate the current so that it is compatible with the requirements of the various data gathering and processing components.

In a preferred embodiment, the integrated handheld field digital data mapping device of the subject invention is capable of:

(1) collecting and mapping global position system (GPS) data;

(2) reporting GPS location, speed, and direction in a seamless fashion;

(3) reporting orientation including magnetic direction, pitch, and roll;

(4) collecting multiple pairs of color, or grey level, digital images (photographs) used to measure distance to an object;

(5) voice command and voice query;

(6) touch sensitive icon control;

(7) providing icon-driven notes relating to field observations;

(8) two-way wireless data transfer with host database station;

(9) mapping the present environment in points, lines, and area features;

(10) providing navigation assistance to a desired location;

(11) power management to allow a battery pack to provide power to various components;

(12) collecting infrared images;

(13) bar code reading;

(14) voice/audio annotating;

(15) video annotating;

(16) WEB/Ethernet phone function;

(17) fingerprint recognition;

(18) digital inking;

(19) native methods/Applets as internet compliant design;

(20) ethernet;

(21) PC card; and

(22) touch/pen input.

Brief Description of the Drawings

Figure 1 is a block diagram showing the components of one embodiment of the device of the subject invention.

Figure 2 is a schematic showing the determination of the distance to an object from the device of the subject invention using the images produced by two digital cameras.

Figure 3 is a schematic of the embedded controller processor system.

Figure 4 is a schematic of the digital compass and inclinometer.

Figure 5 is a schematic of the flash memory subsystem.

Figure 6 is a schematic of the GPS receiver subsystem.

Figure 7 is a schematic of the LCD display subsystem.

Figure 8 is a schematic of the touch screen interface and module.

Figure 9 is a schematic of the stereo digital camera subsystem.

Figure 10 is a schematic of the digital stereo range finder subsystem.

Figure 11 is a schematic of the voice command subsystem.

Figure 12 is a schematic of the wireless network interface.

Figure 13 is a block diagram of an embodiment of a GDM in accordance with the subject invention.

Figure 14 is a diagram of object oriented control of a camera subsystem as a JAVA native method, in accordance with the subject invention.

Figure 15 is an illustration of a handheld GDM, in accordance with the subject invention.

Figure 16 is an illustration of a GDM which can be incorporated with a vehicle, in accordance with the subject invention.

Figure 17 shows the basic functional modules of a GDM, in accordance with the subject invention.

Figure 18 illustrates a camera module of a GDM, in accordance with the subject invention, which utilize a Dycam digital camera with two CCD sensors.

Figure 19 illustrates a camera module of a GDM, in accordance with the subject invention, which utilizes mirrors to relay an image from the left optics and an image from the right optics to a high resolution CCD detector.

Figure 20 illustrates an embodiment of a GDM, in accordance with the subject invention, which utilizes two GPS antennas and two image gathering optics.

Figure 21 illustrates an embodiment of a GDM, in accordance with the subject invention, which utilizes a gyroscope to provide data related to the GDMs heading, pitch, and/or roll.

Detailed Disclosure of the Invention

The subject invention provides a system design, materials and methods which are highly advantageous in collecting and utilizing field data for use in a wide variety of

applications. The Geographic Data Manager (GDM) of the subject invention is a multi-component system for gathering positional, image, and other data, and simultaneously processing this information. The subject invention is also applicable to other tasks such as construction and utility monitoring, environmental sampling, surveying, agricultural field data collection, law enforcement, public safety, and property appraisal. Specific applications include the gas, water, sewer, telephone, and cable TV utilities; local, state, and federal government inspection agencies; and the insurance and transportation industries.

Referring to Figure 17, a block diagram is shown illustrating the main functional blocks of the subject invention. In a preferred embodiment, the GDM of the subject invention comprises a central processor unit (CPU) **1**, preferably a low power microprocessor, which coordinates the transmission and receipt of data and commands from the other system components and processes the data gathered, stored, and/or processed, in order to provide data needed during the operation of the subject GDM. High speed data links **2** can link the central processor unit **1** to the camera module **3**, a user interface module **4**, a directional and orientation module **5**, a location module **6**, a power module **7**, and an optional network communication module **8**.

The camera module **3** can gather data representing digital images of objects under study. The camera module **3** can receive control signals from the CPU **1** and send data representing digital images to the CPU **1** for storage and/or processing. The user interface module **4**, connected to the CPU **1** by a high speed data link **2**, allows a user to interface with the GDM. The user interface **4** can allow a user to view images stored in the GDM, an object currently in the camera(s) view, and/or icons which can allow the user to control the operation of the GDM. The user interface **4** can utilize voice recognition and commands, a heads up display, computer display flat panel with pen or touch input, and/or various other user interfaces.

The directional and orientation module **5**, connected to the CPU **1** by a high speed data link **2**, supplies data to the CPU **1** which is used to determine the heading, pitch, and/or roll of the GDM and can also receive data from the CPU **1**. For example, the CPU **1** can send data which the CPU **1** receives from the location module **6**, which can be

useful in calibration of the equipment of the directional and orientation module 5. Compasses, inclinometers, gyroscopes, and/or combinations of GPS receivers can be utilized for collection data which is relevant to the direction and orientation of the GDM.

The location module 6, connected to the CPU 1 by a high speed data link 2, gathers and sends data to the CPU 1 which can be utilized to determine the location of the GDM. The location module 6 can utilize a variety of systems to gather this data, including, for example, satellite and/or ground based positioning systems. In a preferred embodiment of the subject invention, the location module utilizes GPS antennas and receivers to receive satellite signals which allow the CPU 1 to determine the position of the GDM. In specific embodiments, the directional and orientation module 5 and the location module 6 can be combined, for example when three GPS antennas and receivers are utilized to provide data relevant to position, pitch, and/or roll of the GDM.

The optional network communication module, connected to the CPU 1 by a high speed data link, can be utilized to enable the GDM to communicate with remote facilities, for example a home office computer which can receive and send data from and to the GDM. The network communication module can utilize, for example, wireless or wired networks. In a specific embodiment, at least two GDMs can communicate with each other via network communication modules, for example, to transfer data.

The handheld data gathering device of the subject invention can, in a preferred embodiment, comprise:

(a) An imbedded computer capable of storing and processing image data and interfacing to multiple data sensing modules. The user sees the graphical and alpha numeric results on a LCD or appropriate display with pen and/or touch screen input, either color or black and white. The user controls the system through touching or pointing to action icons or via voice commands. Alternatively, a mouse and keyboard may be used for more conventional user input and control of the system

(b) A global position receiver (GPS) capable of accurately capturing geographic location with post processing or real-time differential correction capability. Better than one meter accuracy can be achieved with such a system. An interface from the GPS to the central computer to

process the location data and the necessary software to display and record the results. Differential correction of GPS data is used to improve the accuracy either real-time or post processing as available.

(c) A digital compass capable of providing accurate heading. Other devices capable of providing heading, for example, a gyroscope or a pair of GPS receivers, can be used to calculate heading. A gyroscope can be calibrated from heading obtained from the GPS receiver when the GDM is moving. In a specific embodiment, a digital compass can be utilized with an error of less than about one degree. An interface from the digital heading device to the central processor and software capable of processing and displaying and storing the direction or heading information.

(d) Means capable of providing accurate pitch and roll data, for example digital inclinometers. Accurate pitch and roll data, for example less than one degree of error, for a plane parallel to the center line of the camera's field of view can aid in resolving the exact location of the object under observation. For example, available digital inclinometers can be utilized with an error of less than about one degree. A gyroscope type device and/or a set of GPS receivers can also be used to collect real-time orientation data. The interface from, for example, an inclinometer, to the imbedded computer transfers the pitch and roll data. The system software is responsible for processing, displaying and storing the pitch and roll data. It also makes the data available for use in calculating new coordinates.

(e) A pair of digital cameras with matched optics mounted with the lenses in the same plane and with the line through the center of view of each lens parallel to the line through the other. An interface from the cameras to the imbedded computer processor and software capable of displaying, processing, and storing the images.

(f) Stereo image processing software or hardware algorithms capable of locating a selected object in one image in the stereo image pair. Once the object is located in the stereo pair image the displacement between the two objects is used in conjunction with the optical characteristics of the lenses and the spacing of the lenses to calculate distance to the object of interest. Accuracy of plus or minus one inch can be achieved at fifteen feet, and about plus or minus a foot at thirty feet can be readily achieved using lenses which are only about nine inches apart. The distance accuracy drops off as the distance increases; however, longer range accuracy is achieved by sliding the cameras out to a wider spacing and/or attaching telephoto lenses to the cameras. For example, a 2x telephoto lens makes the accuracy plus or minus one inch at 30 feet. The GDM can be made with lenses spaced at nine inches to keep the handheld unit small; however, when extended to 18 inches the accuracy is increased. The GDM can have a horizontal resolution of 640 pixels. Image sensors with a higher resolution also increase distance accuracy. For maximum distance accuracy a higher resolution sensor is used in conjunction with widely spaced lenses and telephoto lenses

(g) In addition to simple distance measurement and range finding to locate an object of interest to the user the pair of stereo images collected can be used to measure objects of interest in the field or at a later time by storing the optical characteristic of the lenses and the lenses spacing with the stereo pair of images produced.

(h) Data stored in the system in the PC Card or appropriate computer storage medium can be sent to a base unit via a wireless network which can be made up of two-way digital packet radios or analog or digital cell phones. Alternatively, data can be exchanged via an infrared link, a serial cable, a modem on the phone system, a wired network connection, Ethernet, a PC Card, a floppy disk, or other available channels.

(i) Voice communications between units can be provided over the digital data link to aid in coordination activity of the users in the field.

(j) The software of the prototype system is designed to enhance the use of the Internet base world wide web. A real time operating system can be used to manage each of the devices such as the cameras; GPS or multiple GPS receivers; the direction and orientation devices; the wireless or wired network interface, the battery and power management subsystem; the graphics display; and the audio input and output devices. In the prototype system Java native methods are provided for each device. For example there is a Camera object which provides the Web based Java program with stereo digital image pairs and range finding calculations.

(k) A power management system designed to maximize the usable battery life of the GDM by regulating the use of power by the main computer system as well as each of the data collection subsystem devices.

In a preferred embodiment, the GDM of the subject invention utilizes a pair of digital cameras which are not only able to provide photographic images of sites of interest but also to facilitate the determination of the distance from the GDM to any object in the images produced by the digital cameras. The distance determination can be carried out by the GDM utilizing a software program which compares the images produced by the two cameras in order to determine the distance apart a single object is in the two images. Referring to Figure 2, this distance apart in the images is directly proportional to the distance that the object is from the GDM. The distance to an object can be determined from the following relationship:

$$d_o = \frac{fd_c}{d_i}$$

where d_o is the distance to the object,

d_c is the spacing between the cameras,

d_i is the offset of the two images of the object from the cameras, and

f is the focal length of the cameras' lenses.

Through a series of straightforward computational steps, the GDM of the subject invention analyzes the distance between the object's images and converts this to the distance from the GDM to the object.

In a preferred embodiment, the subject GDM can have stereo camera lenses which are precisely rotated on an axis through a line through the center of the optics of each lense. Rotation of the lenses such that each points toward the object under study can allow a more precise determination of the distance to an object. In this embodiment, the first image set can be taken with the lenses parallel. The distance to the object can be calculated and this distance used to compute the angle of rotation for each lense. The two images of the same object are then matched by small changes in the angle of rotation. The final range can be calculated utilizing the angle of rotation of the lenses.

In a preferred embodiment, the GDM simultaneously records the pitch and roll of the GDM as determined by, for example, an inclinometer, and it records the magnetic direction of the GDM as determined, for example, by a digital compass. This information, together with the GPS information, are all processed essentially simultaneously by the CPU and can be, for example, transmitted to a remote host computer by wireless communication components.

The following two tables illustrate the accuracy of distance determination utilizing two specific embodiments of the subject invention. In these tables, one pixel depth gives the range expected error for one pixel alignment accuracy of the image.

Table 1				
Range To Target In Meters	Image target offset in mm	Image target offset in pixels	One pixel depth Meters	View frame in Meters
3	2	363	0.008	0.88 by 0.60
5	1.2	218	0.021	1.45 by 1.1
10	0.6	110	0.090	2.9 by 2.2
25	0.24	43	0.51	7.5 by 5.5
50	0.12	22	2.0	14.5 by 11

Table 2				
Range To Target In Meters	Image Target Offset in mm	Image Target Offset In Pixels	One Pixel Depth Meters	View Frame In Meters
10	2.4 mm	436	0.0225	2.96 by 2.2
25	0.96 mm	175	0.1273	7.5 by 5.5
50	0.48	86	0.50	14.5 by 11
100	0.24	22	2.00	29 by 22

Table 1 is for 12 mm lenses set at 500 mm lenses spacing and a 0.0055 mm per pixel CCD sensor, which can be utilized in a handheld GDM in accordance with the subject invention. Table 2 is for 12 mm lenses set at 2 meter lense spacing and a 0.0055 mm per pixel CCD sensor, which can be utilized in a vehicle mounted GDM in accordance with the subject invention.

A variety of options relating to imaging optics can be utilized in accordance with the subject invention. Referring to Figure 20, a left camera sensor and optics and a right camera sensor and optics can feed two digital cameras, each having a sensor, or one digital camera having two sensors. Referring to Figure 19, mirrors can be used to guide the right and left images to a single high resolution CCD detector. Other variations can be readily utilized by one skilled in the art having the benefit of the instant disclosure.

The GDM of the subject invention can further comprise a display screen and a means for the operator to interact with the GDM. This means of interaction may be, for example, by a touch screen, by voice recognition, or by a traditional keyboard.

A person skilled in this art having the benefit of the instant disclosure would readily appreciate that a variety of modifications could be made to the specific embodiments exemplified herein without departing from the spirit of the instant invention. For example, the GPS function of the GDM is for the purpose of providing a location for the GDM. This function could be performed by other locating means including, but not limited to, other satellite positioning systems and ground-based systems. Certainly, when the device of the subject invention is to be used indoors or in the vicinity of tall buildings, it may be advantageous to use a ground-based location system rather than a satellite system. Also, the device could display a map which the user could touch or in some other way designate the location of the GDM. In yet another embodiment, the GDM may be stationary, in which case its position will be known.

The subject GDM can be utilized in applications where the determination of an object's location in two-dimensions is required, for example when the height of the object is not needed. In a specific embodiment, referring to Figure 20, the subject GDM can be equipped with two GPS antennas and two cameras which can allow the determination of the object's location in two dimensions. In this embodiment, the two GPS antennas can be offset such that a heading and position of the GDM can be determined and the two digital cameras can provide the distance to the object, thus providing data needed to determine the object's location in two dimensions. Alternatively, a compass can provide the heading and two cameras can be used to provide the distance to the object from the location of the GDM. In another alternative embodiment, for example, if the direction of an object is known, an inclinometer and the two digital cameras can provide pitch and distance data which can be used to determine the height and distance to the object from the location of the GDM.

In a preferred embodiment, the subject GDM can comprise at least three GPS antennas and corresponding receivers, wherein the GPS antennas are in a plane. The receipt of the signal from one GPS satellite by all three of the GPS antennas can provide

information with respect to pitch and roll of the GDM, as well as location. Accordingly, when this information is combined with the distance information determined from the images from the at least two cameras, the GDM can provide information as to the exact location, in three dimensions, of the imaged object. Advantageously, the combination of the three GPS antennas can provide a more accurate determination of the GDM location due to receipt of the GPS signals by all three GPS antennas in a plane.

In another specific embodiment, referring to Figure 21, the subject GDM can comprise at least one gyroscope, for example a laser gyroscope, which can provide data related to the GDM's heading, pitch and/or roll. Advantageously, a laser gyroscope can be less susceptible to confusion by metals than a compass. In addition, a gyroscope can be calibrated from data received from the GPS when the GDM's GPS is moving.

In a further embodiment, the subject GDM can be incorporated with another structure, for example a vehicle. This other structure can incorporate at least one GPS antenna and a means for providing data to the GDM with respect to the GPS antenna's position relative to the GDM's camera(s). This embodiment can be useful when the GDM is used, for example near tall buildings, where the GPS satellite signals can bounce off and/or be blocked. The GDM can also have a means for mounting to a structure, for example a vehicle, such that its location relative to the structure is known. In a specific embodiment, the GPS antennas can be mounted on a structure in order to allow a greater distance between the antennas and, therefore more accurate distance determinations.

Referring to Figure 16, a specific embodiment of the subject invention is shown which can be used in a vehicle such as an automobile, boat, airplane, or helicopter. In this specific embodiment, two GPS antennas, two cameras, and a gyroscope are incorporated into data bar which can be mounted on a vehicle by way of a base mount. Advantageously, this can allow a large spacing between cameras and, therefore, very accurate distance determinations. The data bar is connected to a user interface by a high speed data link. This data link can be wired or wireless. The central processor unit can be located within the data bar with the user interface being a peripheral attachment, or the central processor unit can be in the user interface unit. The user interface unit can be mounted in the vehicle to free a user's hands or can be held by a user during use. Other

combinations of components and mounting techniques can be readily designed and used by a person skilled in the art having the benefit of the instant disclosure.

In an alternative embodiment, a handheld user interface unit can have a gyroscope and two cameras with a GPS antenna being attached to a vehicle. A user can position the vehicle such that a GPS signal is available to provide the location of the GDM. Once the GDM position is known and the gyroscope in the hand held unit is calibrated, the user can approach objects in regions where a GPS signal may or may not be available, for example inside a building. The GDM can keep track of the movements of the GDM by data received from the gyroscope in order to assist in the determination of the position of imaged objects. This can enable the use of the subject GDM in environments where a useable GPS satellite signal is not necessarily available. In a specific embodiment, a set of accelerometers and a set of gyroscopes can provide dead reckoning position calculation where a reliable GPS signal is not necessarily available.

Another embodiment of the subject invention utilizes more than two cameras in order to provide enhanced spatial determination of an object. In another embodiment, the cameras of the subject invention can be moved to increase the distance between the lenses so as to enhance the accuracy of distance determinations, especially for objects located at a substantial distance from the GDM. The moveable camera lenses can be retractable to their original position for convenience. The camera may utilize wide-angle lenses for objects close to the GDM.

Cameras and/or camera lenses which are based on different parts of the spectrum, for example infrared, may also be utilized in accordance with the subject invention. In a specific embodiment, the camera may include an infrared sensor for heat detection. The GDM may be equipped with additional chemical and environmental sensors to augment the type and amount of data which can be gathered.

In a preferred embodiment, the GDM of the subject invention will have a real-time operating system to coordinate the essentially simultaneous collection of multiple types of data.

The connections and interfaces of the various components of the GDM of the subject invention can be designed and produced by one skilled in this art having the benefit of the teachings provided herein.

Following are examples which illustrate procedures for practicing the invention. These examples should not be construed as limiting.

Example 1 – Handheld Portable GDM

In a specific embodiment, referring to Figure 1, the GDM of the subject invention can run Microware's OS-9 (OS-9 Version 3.0 Documentation, 1995 Microware Systems Corp., Des Moines, Iowa) embedded operating system from ROM. The heart of the computer is a Gespac SBSG8-10 (Gespac Inc., Mesa, AZ) with two megabytes of ROM and one megabyte of static RAM. It has a Motorola 68340 CMOS low power processor with six serial ports. See Figure 3.

A small carrier board holds two industry pack modules. The first has a GreenSprings IP-LCD VGA (Greenspring Computing Inc., Menlo Park, CA) controller interfaced with a small Sharp 640 x 480 TFT active matrix flat panel color screen. The color screen displays digital images, maps, and other data for verification and collection. See Figure 7. The second industry pack module is a storage module with eight megabytes of flash memory. See Figure 5.

The user interacts via a Dynapro touch screen (Dynapro SC3 Touch Screen Controller and Software Users Reference Version 1.1, 1995, Dynapro Thin Film Products) on the sixth serial port and/or via voice prompting and command provided by a OKI semiconductor voice control module connected to the first serial port. See Figures 8 and 11.

A stereo pair of Gator Digital cameras (Gator Digital Camera Users Guide and Reference, 1994, Dycam, Chatworth, CA) are attached to the second serial port via a high speed synchronous connection. The two cameras provide stereo pairs of images for depth-of-field calculations and three-dimensional digitizing of objects of interest. See Figures 9 and 10.

An eight-channel Trimble GPS receiver (Trimble Navigation, Sunnyvale, CA) is on the third port. A DCI differential correction receiver which corrects the GPS data to 1-2 meter accuracy is connected directly to the GPS receiver. See Figure 6.

A Precision Navigation digital compass unit provides direction, pitch, and roll, as well as temperature, on the fourth port (Precision Navigation TCM2 Electronic Compass, 1994, Precision Navigation, Mountain View, CA). See Figure 4.

Another port is used for communication using a Digital Wireless spread spectrum which communicates at distances of up to one mile line-of-sight. The wireless packet radio link uses the tcp/ip protocol for compatibility with sending and receiving data over the Internet. See Figure 12.

The graphical user interface can be based on G-Windows (G-Windows and G-View Developers Manual, 1995, Gespac S.A., Geneva). G-Windows can run completely from ROM and provides an effective interface. G-View, a widget builder, is used for constructing object-oriented widgets to control the data sensors. The touch-sensitive color screen is used to display color and black-and-white digital images of objects under study and is used in the object documentation process. Objects are digitized by translating the GPS location of the data mapper to the object. The distance is calculated from the user touching the object of interest in the digital image and the computer automatically finding the same pattern in the stereo pair image. Bearing and orientation are calculated from the compass and inclinometer reading.

When in voice command and control mode, the system verbally prompts the operator for input and flashes the appropriate icon when the voice command from the user is processed. This leaves the operator's hand free for other tasks. The voice command and control also aids in poor visibility situations and for users with visual handicaps.

Example 2 – Measurement of Remote Objects

Objects of interest can be measured in the field by touching two points on one picture and letting the system calculate a three dimensional coordinate for each point from the direction, pitch, and roll data, lens characteristics and lens spacing. Distance between points can be calculated. All of the data is stored with the stereo pair of images

for future processing with similar software on a desktop computer and/or if the user desires to capture more detailed information from the photo.

Example 3 – Three Dimensional Digitizing of Objects

As the user points the data collector unit in the direction of an object of interest the GPS is providing location coordinates, the system is also monitoring the direction pitch and roll of the stereo pair of cameras. Once the relative three dimensional coordinate for the object under study is calculated from the stereo data and the three dimensional heading of the camera the actual location of the object is calculated and recorded.

Example 4 – Mapping Objects in the Field

The coordinate derived for the objects located in the stereo pairs of images is used to construct a geographic information system map layer. Each object can have attribute data stored with it including a photo of the object, its dimensions, and other attribute data the user desires to include. For example a verbal description can be digitized by the voice processor for a tag attribute or an icon driven system can be used to capture field observations.

Example 5 – Special Processing of Pictures

Each stereo pair of pictures has location and directional data stored with it thus the plane of the photograph is known. This makes it possible to correct the picture for orientation. For example if the picture was taken at an angle the image can be rotated to remove the tilt in the picture. Also a floating scale is placed on the surface of an object in a picture so dimensions can be directly read off by the user. The units on the scale are automatically set from the information obtained from processing the stereo images and their associated data.

Example 6 – Field Correction of Existing Geographic Information System Data

Existing data is corrected in the field by loading an existing map data set on to the system. The user takes the map into the field. As features on the map are

photographed the user touches the object on the map and the same one in the stereo pair of pictures. The system automatically calculates the displacement to the object and translates the GPS coordinate of the handheld data mapper to the object. This new accurate coordinate is then used to update the old feature coordinates including adding an altitude coordinate.

Example 7 – Generation of Three Dimensional Wire Frame Sketches

Several algorithms are used to enhance the edges of objects of interest. For example the lapse transform of an image will highlight the edges of an object in the picture. These algorithms are used to assist the calculation of the displacement measurement of the image pairs of the same objects in the stereo pair of digital photographs. Once the images are highlighted the system can then generate a wire frame three dimensional model for the object under study. In complex situations the user could take several pairs of images from different sides of the object under study. A more complete digital three dimensional map and model of the object is then constructed from the data.

Example 8 — GDM Utilizing the Motorola 821 Power PC Processor

Referring to Figure 13, in another specific embodiment of the subject invention, a GDM was developed around the highly integrated Motorola 821 Power PC processor. This microprocessor has interfaces to PC-card (PCMCIA), RAM memory, flash memory, and LCD display, as part of the chip. The GDM PC-card, RAM memory, flash memory, and LCD display are connected directly to the 821 PPC chip via the respective built in controllers and logic. Some of the advantages of using this processor are low power, small size, and lower cost. Many types of devices can be inserted in the PC-card slot however the most frequent use is to use a solid state hard disk drive to store maps, digital images, and associated data.

The Motorola MPC821 also has a six-channel high speed communication processor. The first channel (SCC1) is connected to an Ethernet transceiver which connects directly to Ethernet local area networks for in office use. The second communication port (SCC2) provides a five megabit synchronous interface to the two

Dycam Gator digital cameras which have a high speed synchronous port provided by their integral digital signal processor (Texas Instruments TMS320cx). The third port (SMC1) is switched between providing a local serial port and the 2.4 gigaHertz spread spectrum two-way digital packet radio. The fourth port (SMC2) is interfaced to a Trimble eight-channel GPS receiver. The fifth channel serial peripheral interface (SPI) is connected to the touch screen controller which provides for user input by touching an LCD panel with a stylus or a finger. The sixth communication port uses the I2C interface (I2C). I2C provides a simple internal network which provides interface to the Duracell DR35 smart battery's I2C port, and the I2C serial interface connected to the Precision Navigation digital compass and inclinometer. When a second GPS receiver is used, the I2C also provides a convenient interface.

The core software for the GDM computer is provided by the Microware OS9000 real time operating system for the Power PC. Device drivers support the interface to all the components attached to the communication channels as well as the LCD graphic display and the PC-card slot. TCP/IP network software provides wired and wireless network interface to the Internet. Sun Microsystems JAVA virtual machine is used to enhance the network features of the GDM. Java classes are provided for each of the major devices which make up the GDM. For example there is a camera class, a compass and inclinometer class, a battery class, and a GPS class. Each of these classes have JAVA native methods written in C or C++ to provide low level access to the data sensors and to do some processing. Figure 14 is a flow diagram of the Camera Class. All of the graphics interface the user sees is written in JAVA, and can be download over the network connection. For a GDM application to take a picture, the application first uses the Camera class to create a camera object which then can be passed messages. For example to capture a stereo pair of digital images the "takePicture" message is sent to the camera object.

Figure 15 provides a representation of a hand-held version of the GDM which is implemented with the system described above. In Figure 15, stereo cameras and stereo GPS receivers are shown. The GPS antennas are mounted at right angles to the lenses on a platform which is attached to the core hand-held computer module at angle α, preferably approximately 150 degrees. This design makes it more convenient for the user

to view images on the screen (live view finder) while taking a picture. Figure 16 illustrates an embodiment of the subject GDM where the stereo GPS and stereo cameras are mounted on a structure which is separate from the user interface. This embodiment is useful in situations where the GDM is used with a vehicle. The structure housing the GPS antennas and cameras can be mounted to the exterior of the vehicle and the computer display module can be mounted to the interior of the vehicle or designed for hand-held use.

It should be understood that the examples and embodiments described herein are for illustrative purposes only and that various modifications or changes in light thereof will be suggested to persons skilled in the art and are to be included within the spirit and purview of this application and the scope of the appended claims.

References

Astec DC to DC converter, Astec America, Inc., Oceanside, CA.

Dibble, Peter (1994) *Insights, An Advanced Programmers Guide to OS-9 3.0 Edition*, Microware Systems Corp., Des Moines, Iowa.

Gator Digital Camera Users Guide and Reference (1994) Dycam, Chatworth, CA.

Dayan, Paul S. (1992) *The OS-9 Guru: The Facts*, Galactic Industrial Limited, Durham, UK.

Dynapro SC3 Touch Screen Controller and Software Users Reference, Version 1.1 (1995) Dynapro Thin Film Products.

G-Windows and G-View Developers Manual (1995) Gespac S.A., Geneva.

Gespac GWSSSS-10 Low Power CMOS MC68340 Single Board System, 1995, Gespac Inc., Mesa, AZ.

Gespac Quad Asynchronous Serial Interfaces XSBSIO-2, 1995, Gespac, Inc., Mesa, AZ.

Greenspring Computer IP-LCD VGA Industry Pack, 1995, Greenspring Computing Inc., Menlo Park, CA.

OS-9 Version 3.0 Documentation, 1995, Microware Systems Corp., Des Moines, Iowa.

Precision Navigation TCM2 Electronic Compass, 1994, Precision Navigation, Mountain View, CA.

Sharp LQ64D142 TFT-LCD Module, 1995, Sharp Liquid Crystal Display Group, 1995, Camas, WA.

Trimble GPS Receiver, 1995, Trimble Navigation, Sunnyvale, CA.

Claims

1. A portable, handheld data gathering device comprising a processing unit which is connected to, and communicates with, components which perform the following functions:

(a) identify position of said device;

(b) provide digital photographic image; and

(c) identify direction of said image relative to said device.

2. The device, according to claim 1, which further comprises a means for wireless communication with a remote host computer.

3. The device, according to claim 1, which further comprises a power source.

4. The device, according to claim 1, wherein said position is identified using the GPS.

5. The device, according to claim 1, which comprises two digital cameras.

6. The device, according to claim 5, wherein the distance between the two digital cameras can be increased or decreased.

7. The device, according to claim 1, which comprises an inclinometer.

8. The device, according to claim 1, which comprises voice recognition capabilities.

9. The device, according to claim 1, which comprises a gyroscope.

10. A device for gathering geographic data, comprising:
a position means for providing the position of said device,

an imaging means for imaging an object, and

a processing means, wherein said processing means can receive and process data from the position means and data from the imaging means in order to provide geographic data for an image object.

11. The device, according to claim 10, wherein said position means comprises a receiver based on a satellite positioning system.

12. The device, according to claim 11, wherein said position means comprises at least one GPS receiver.

13. The device, according to claim 12, wherein said position means comprises at least two GPS receivers.

14. The device, according to claim 10, wherein said position means is a receiver based on a ground based positioning system.

15. The device, according to claim 10, wherein said imaging means comprises two digital cameras, wherein processing data from both cameras provides the distance from said device to an imaged object.

16. The device, according to claim 10, further comprising a heading means for providing a heading of said device.

17. The device, according to claim 16, wherein said heading means is a digital compass.

18. The device, according to claim 16, wherein said heading means is at least two GPS receivers.

19. The device, according to claim 10, further comprising a user interface means for user interaction with the device.

20. The device, according to claim 10, further comprising a pitch means for providing a pitch of said device.

21. The device, according to claim 16, wherein said pitch means is an inclinometer.

22. The device, according to claim 20, wherein said pitch means of said device is a gyroscope.

23. The device, according to claim 20, wherein said pitch means is at least two GPS receivers.

24. The device, according to claim 10, further comprising a roll means for providing a roll of said device.

25. The device, according to claim 24 wherein said roll means for providing a roll of said device is an inclinometer.

26. The device, according to claim 2, wherein said means is a gyroscope.

27. The device, according to claim 24, where said roll means is at least two GPS receivers.

28. The device, according to claim 19, wherein said user interface means is selected from the group consisting of a flat panel display with touch screen, voice interaction, pen commands, and a keyboard.

29. The device, according to claim 10, comprising at least three GPS receivers, wherein data from said three GPS receivers provides a position, a heading, a pitch, and a roll of said device.

30. The device, according to claim 29, comprising two digital cameras, wherein data from said two cameras combined with data from the three GPS receivers provides three dimensional geographic data of an imaged object.

31. The device, according to claim 10, further comprising a means for wireless communication with a remote host computer.

32. The device, according to claim 10, wherein said processing means processes geographic data of imaged objects such that the geographic relation of two imaged objects is provided.

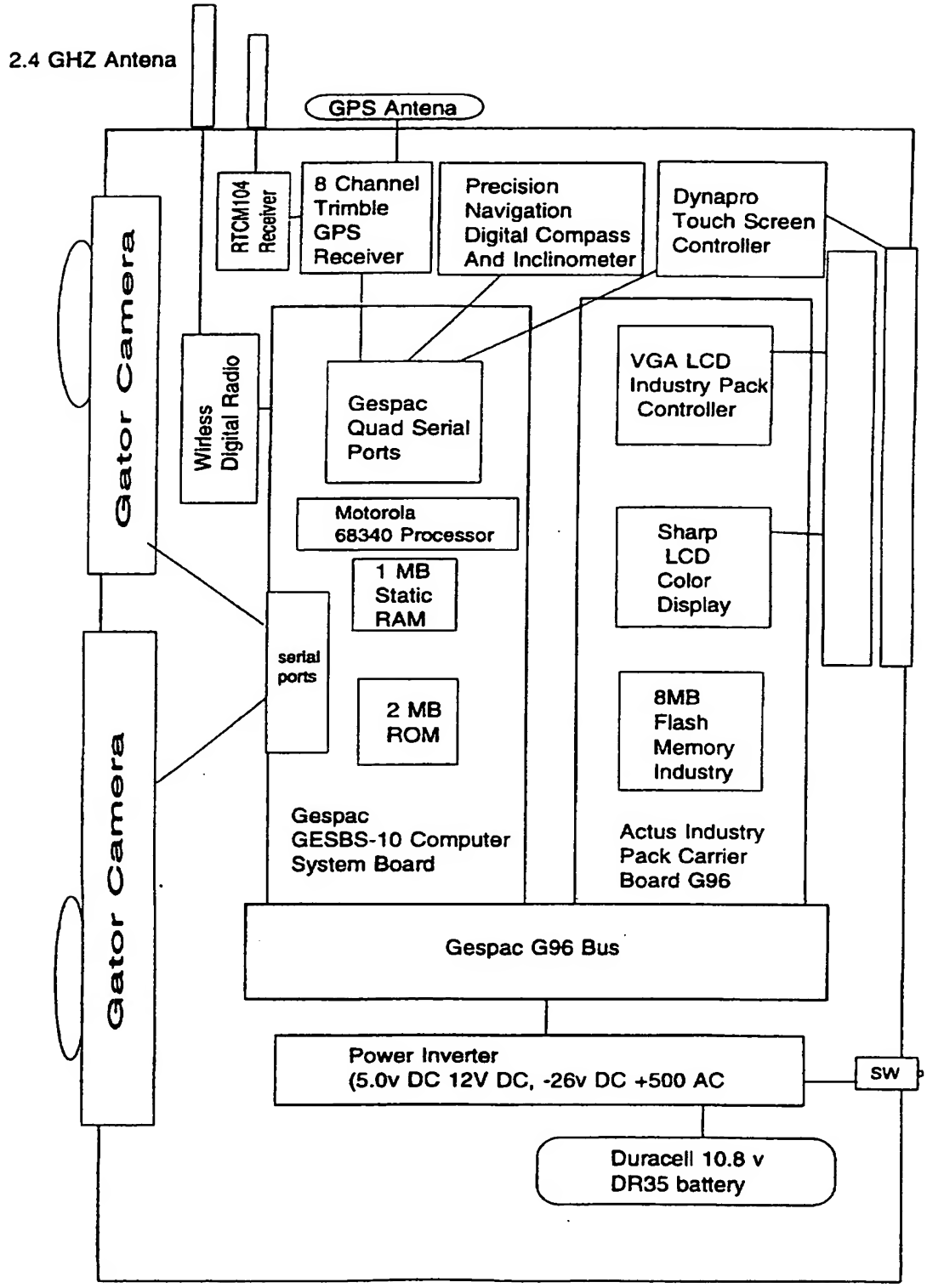

2.4 GHZ Antena
GPS Antena
RTCM104 Receiver
8 Channel Trimble GPS Receiver
Precision Navigation Digital Compass And Inclinometer
Dynapro Touch Screen Controller
Gator Camera
Wirless Digital Radio
Gespac Quad Serial Ports
VGA LCD Industry Pack Controller
Motorola 68340 Processor
1 MB Static RAM
Sharp LCD Color Display
serial ports
2 MB ROM
8MB Flash Memory Industry
Gespac GESBS-10 Computer System Board
Actus Industry Pack Carrier Board G96
Gespac G96 Bus
Power Inverter (5.0v DC 12V DC, -26v DC +500 AC
SW
Duracell 10.8 v DR35 battery

FIG. 1

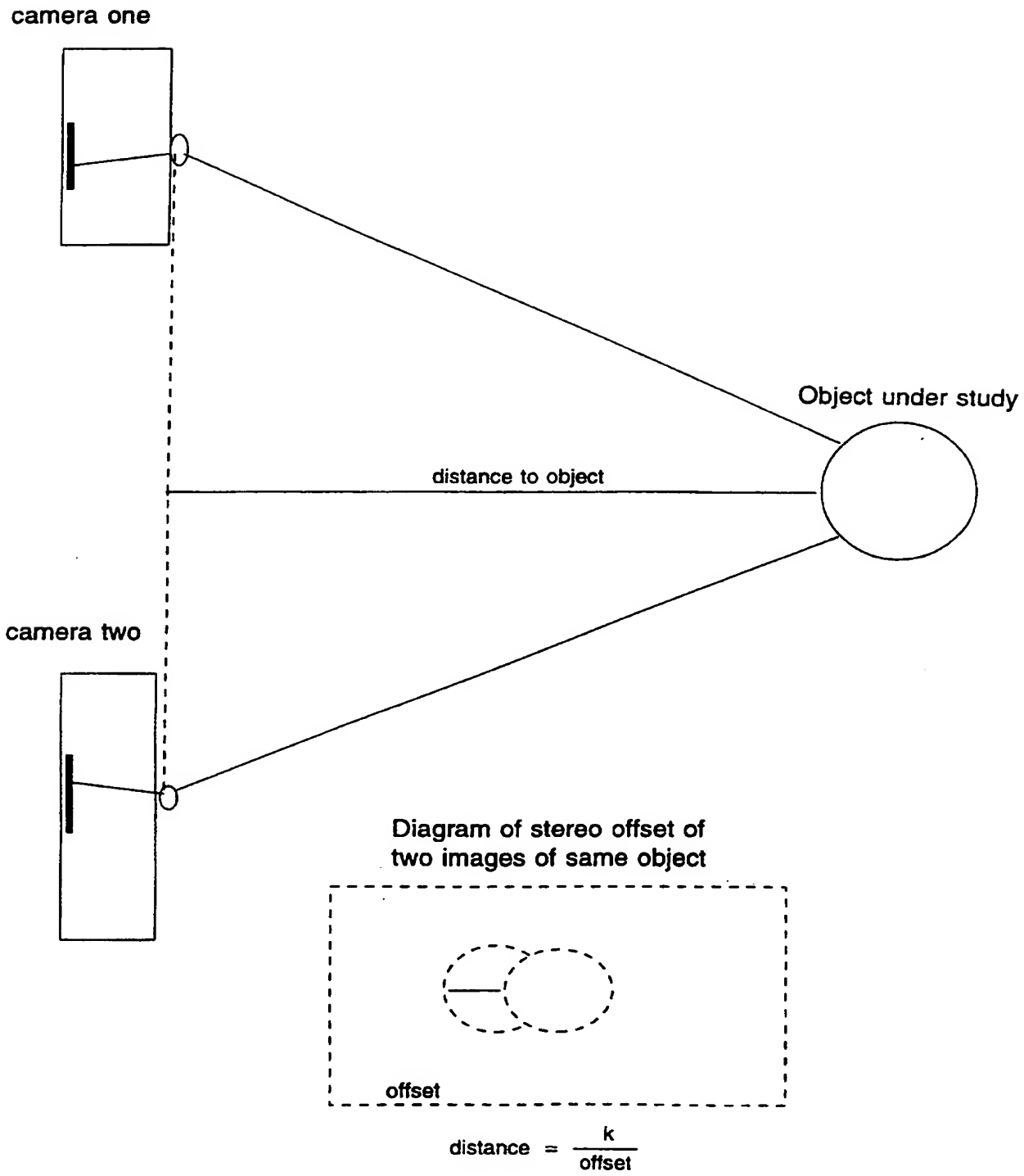

camera one
Object under study
distance to object
camera two
Diagram of stereo offset of
two images of same object
offset
distance = k / offset

FIG. 2

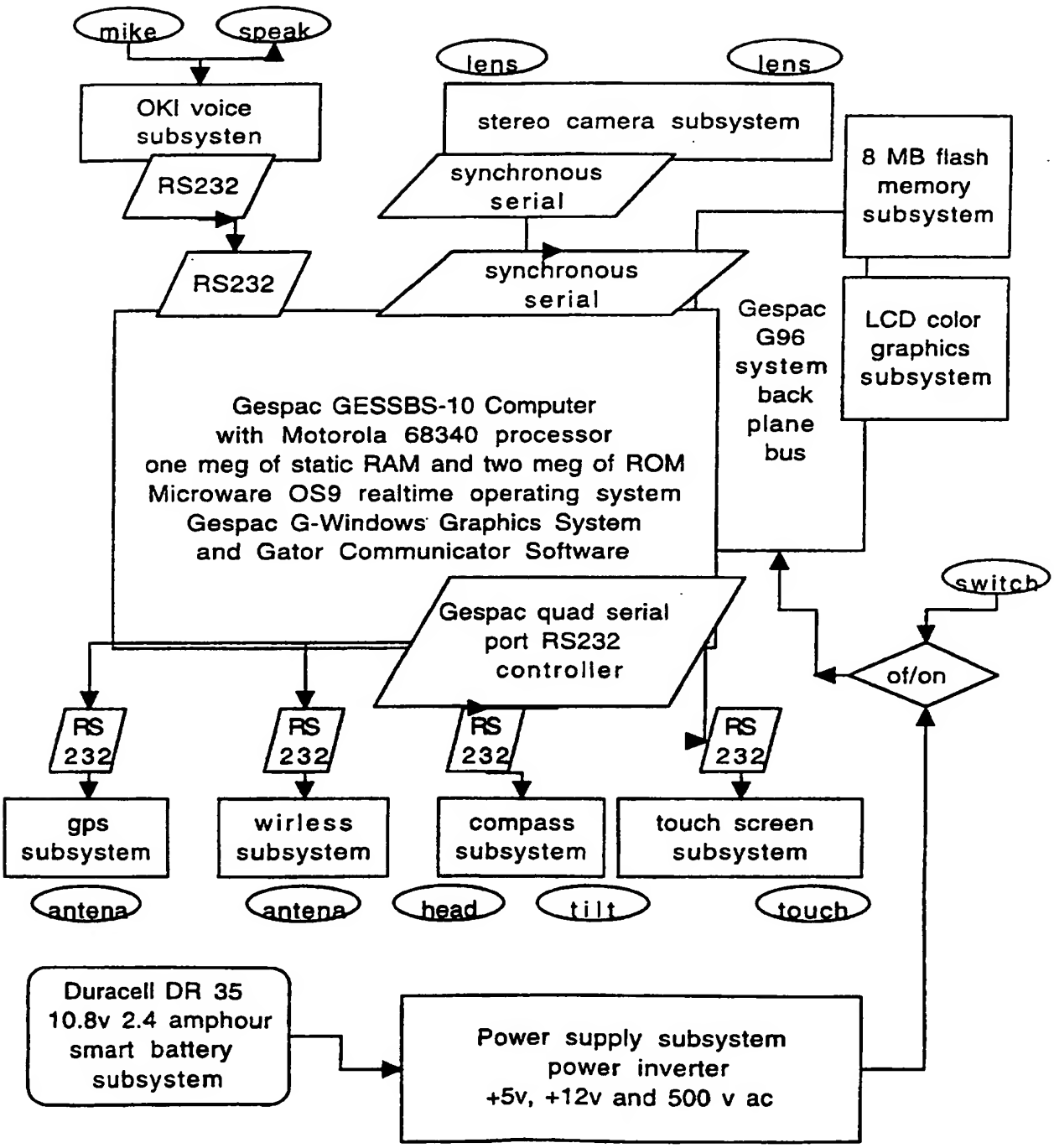

mike
speak
OKI voice subsysten
RS232
RS232
lens
lens
stereo camera subsystem
synchronous serial
synchronous serial
8 MB flash memory subsystem
LCD color graphics subsystem
Gespac G96 system back plane bus
Gespac GESSBS-10 Computer
with Motorola 68340 processor
one meg of static RAM and two meg of ROM
Microware OS9 realtime operating system
Gespac G-Windows Graphics System
and Gator Communicator Software
Gespac quad serial port RS232 controller
switch
of/on
RS 232
RS 232
RS 232
RS 232
gps subsystem
wirless subsystem
compass subsystem
touch screen subsystem
antena
antena
head
tilt
touch
Duracell DR 35
10.8v 2.4 amphour
smart battery
subsystem
Power supply subsystem
power inverter
+5v, +12v and 500 v ac

FIG. 3

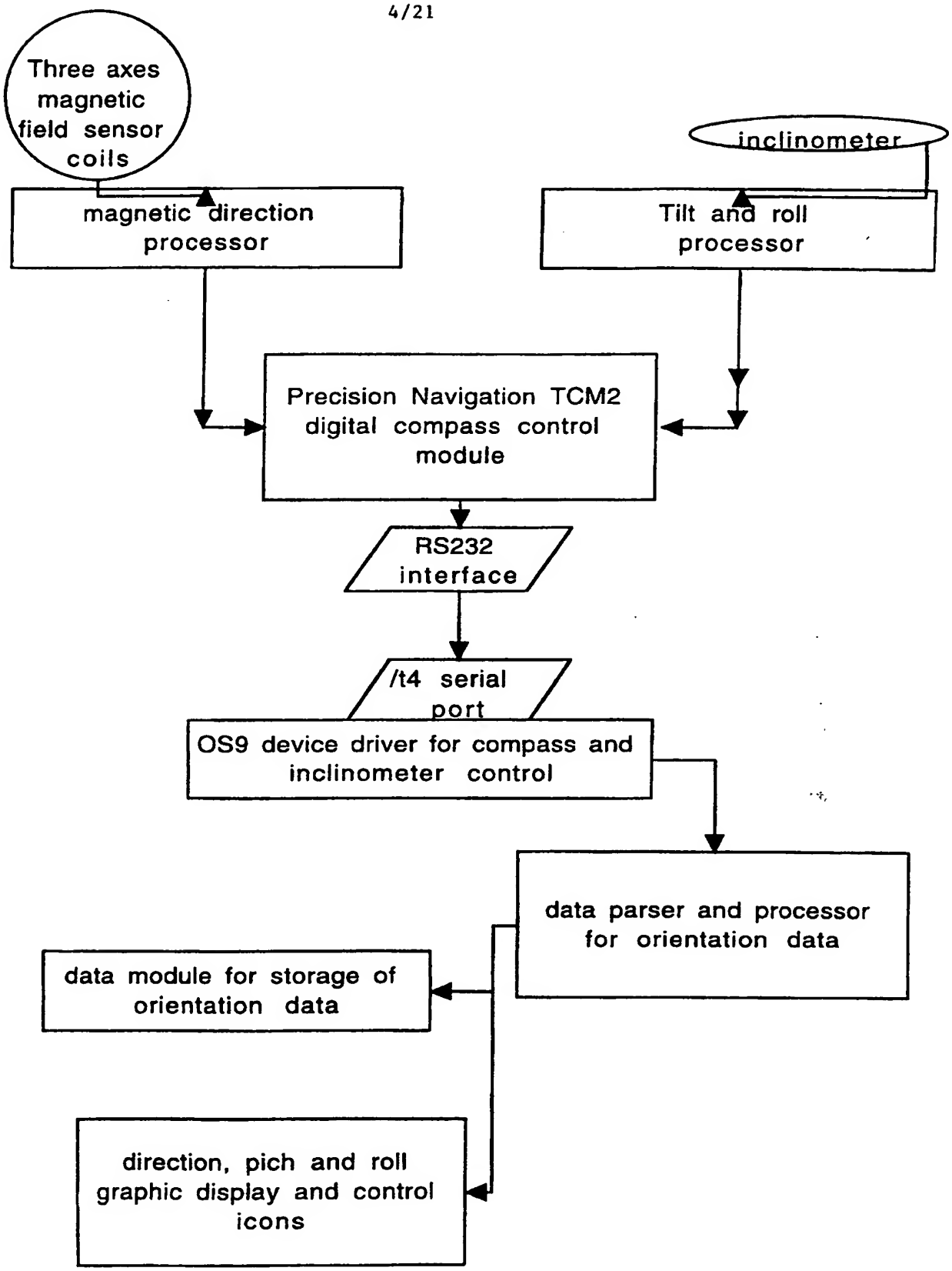

Three axes magnetic field sensor coils
inclinometer
magnetic direction processor
Tilt and roll processor
Precision Navigation TCM2 digital compass control module
RS232 interface
/t4 serial port
OS9 device driver for compass and inclinometer control
data parser and processor for orientation data
data module for storage of orientation data
direction, pich and roll graphic display and control icons

FIG. 4

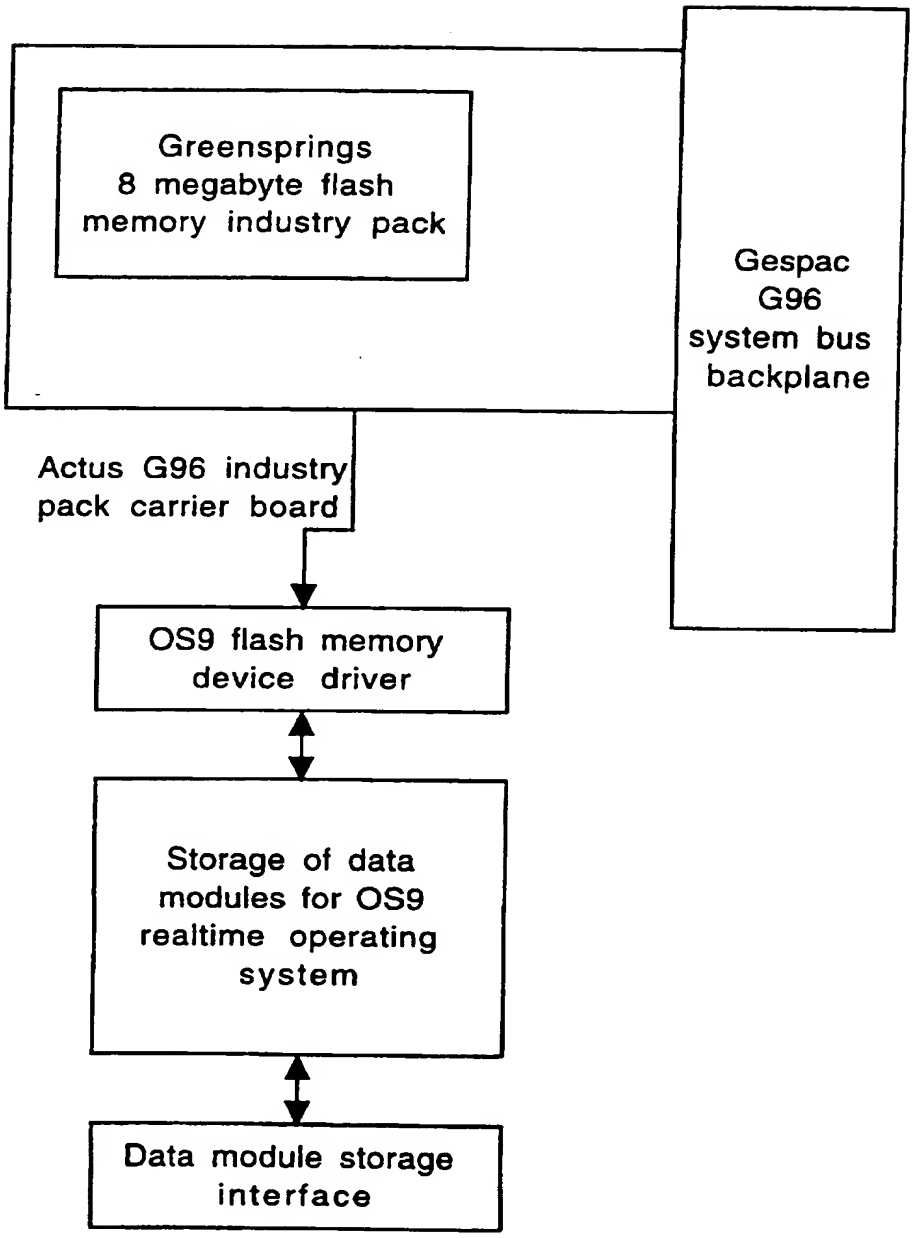

Greensprings
8 megabyte flash
memory industry pack
Gespac
G96
system bus
backplane
Actus G96 industry
pack carrier board
OS9 flash memory
device driver
Storage of data
modules for OS9
realtime operating
system
Data module storage
interface

FIG. 5

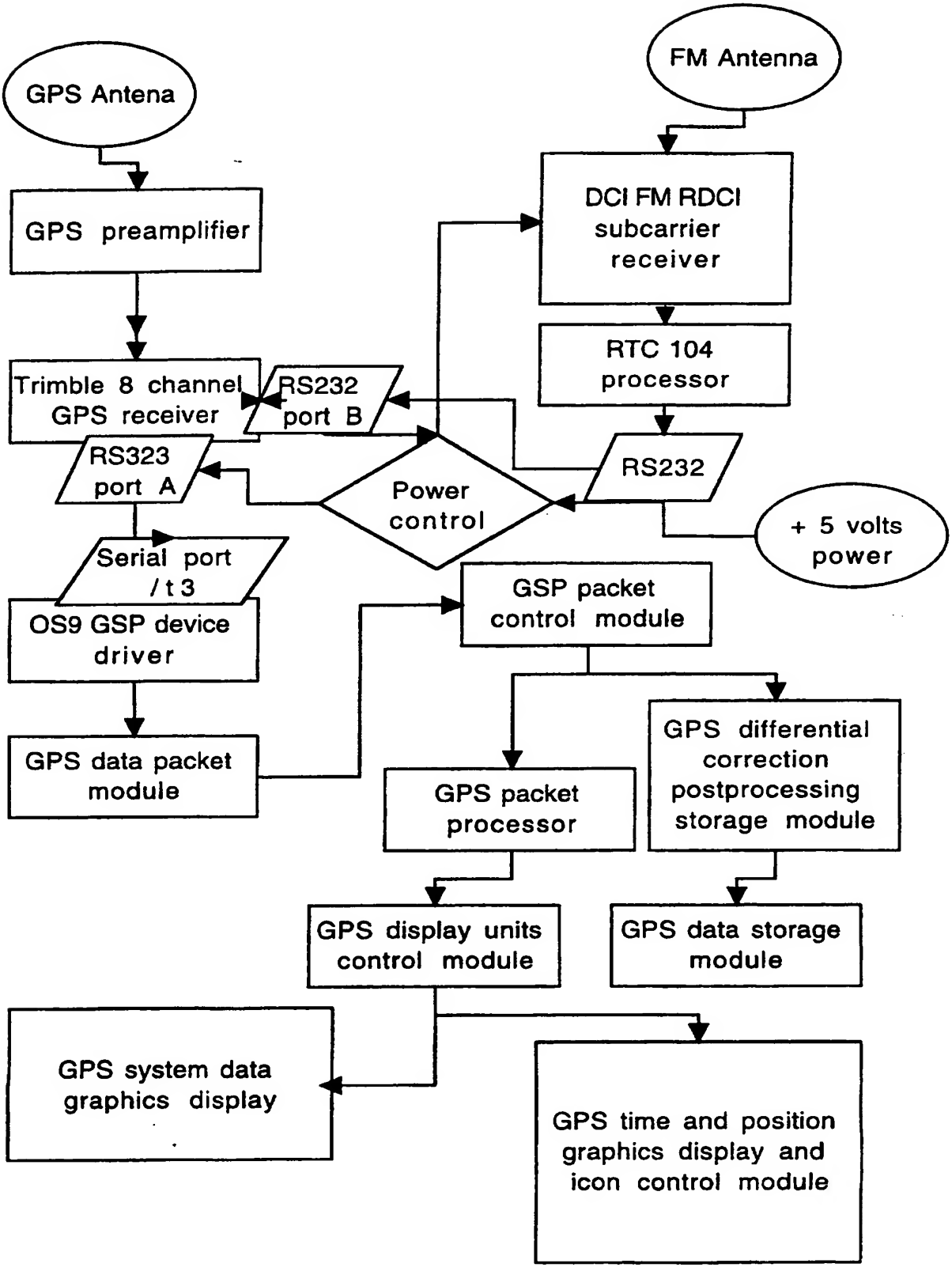

GPS Antena
FM Antenna
GPS preamplifier
DCI FM RDCI subcarrier receiver
RTC 104 processor
Trimble 8 channel GPS receiver
RS232 port B
RS323 port A
Power control
RS232
+ 5 volts power
Serial port /t3
OS9 GSP device driver
GSP packet control module
GPS data packet module
GPS packet processor
GPS differential correction postprocessing storage module
GPS display units control module
GPS data storage module
GPS system data graphics display
GPS time and position graphics display and icon control module

FIG. 6

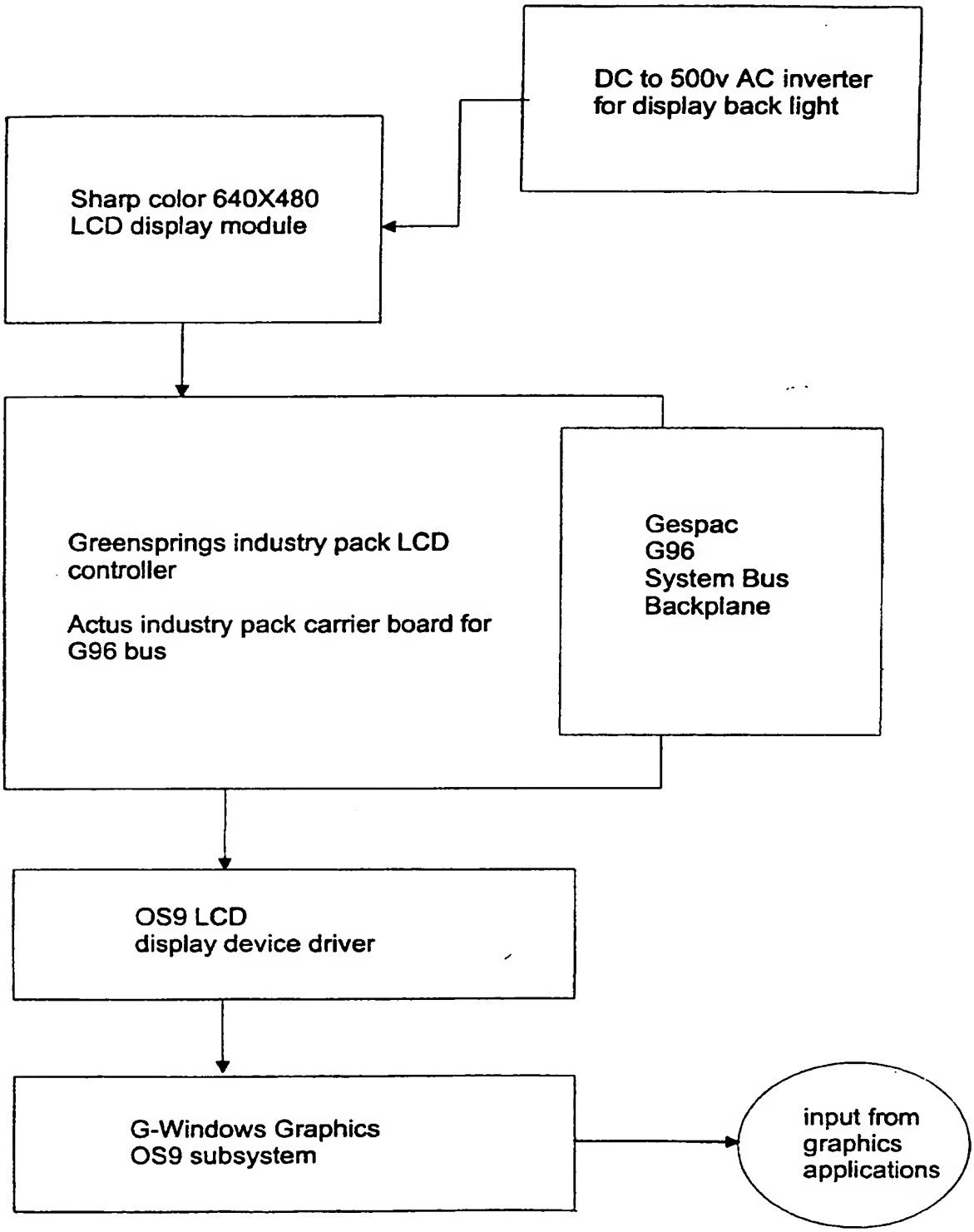

DC to 500v AC inverter for display back light
Sharp color 640X480 LCD display module
Greensprings industry pack LCD controller
Actus industry pack carrier board for G96 bus
Gespac G96 System Bus Backplane
OS9 LCD display device driver
G-Windows Graphics OS9 subsystem
input from graphics applications

FIG. 7

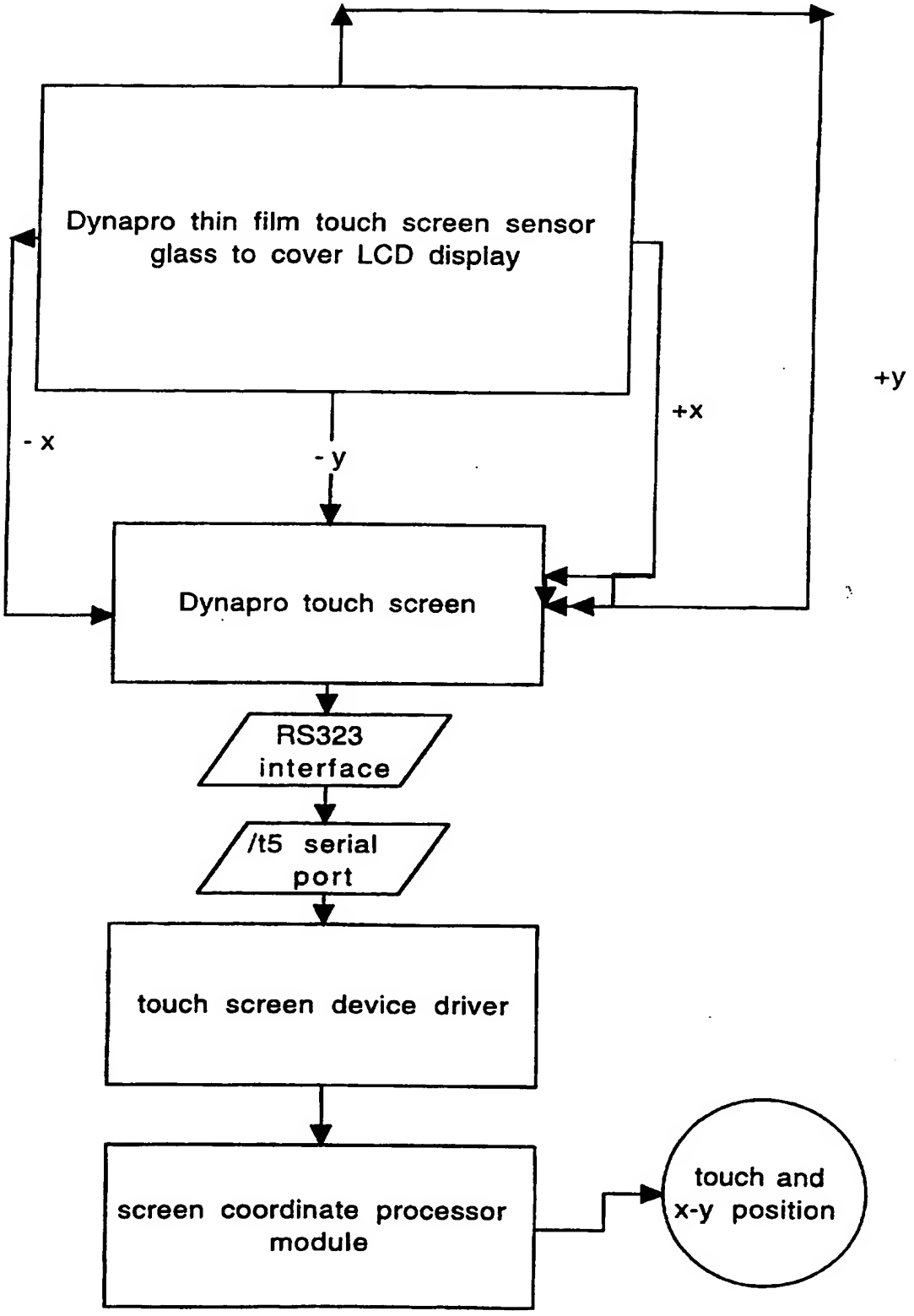

Dynapro thin film touch screen sensor glass to cover LCD display
+y
+x
- x
- y
Dynapro touch screen
RS323 interface
/t5 serial port
touch screen device driver
screen coordinate processor module
touch and x-y position

FIG. 8

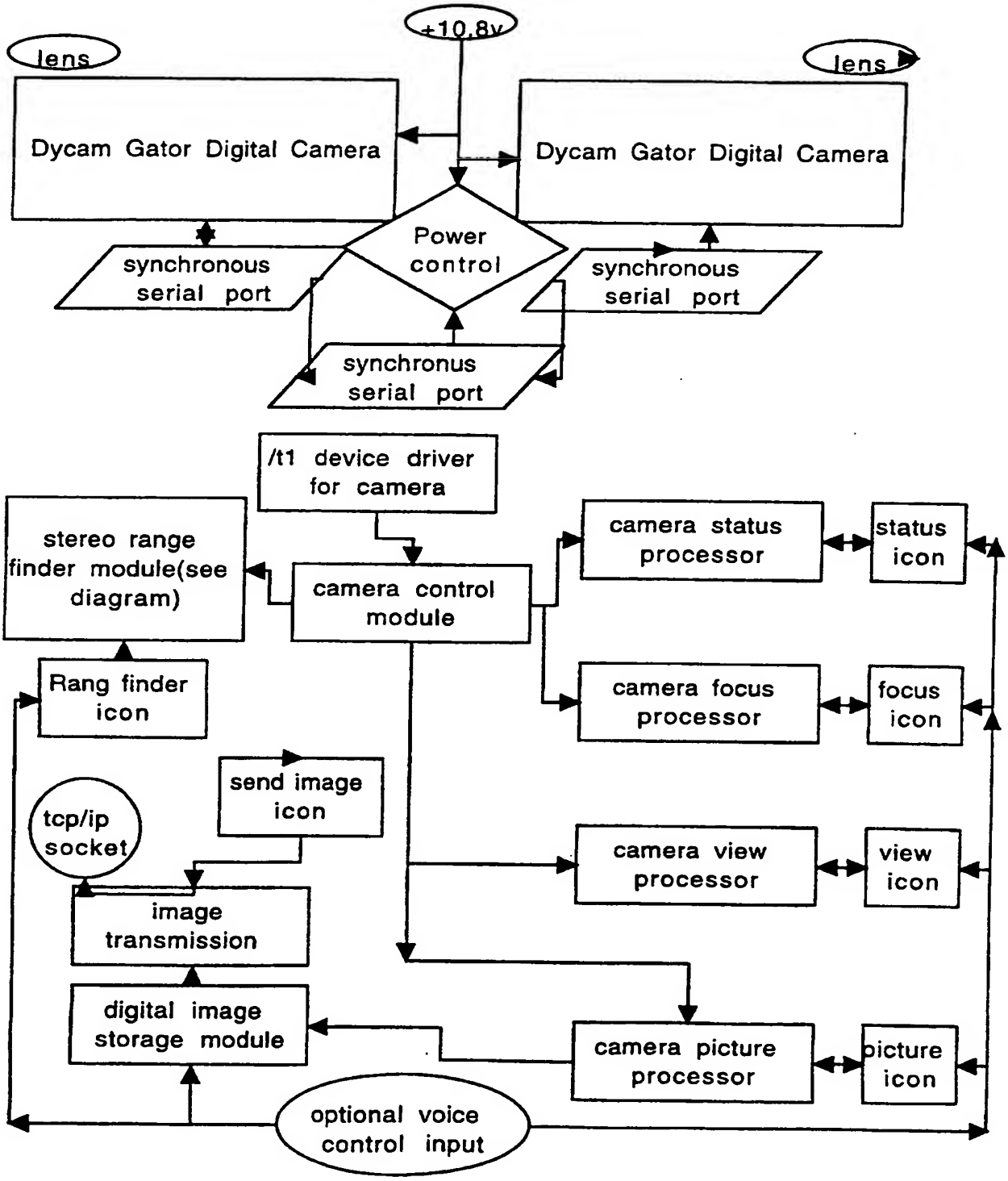

+10.8v
lens
lens
Dycam Gator Digital Camera
Dycam Gator Digital Camera
Power control
synchronous serial port
synchronous serial port
synchronus serial port
/t1 device driver for camera
stereo range finder module(see diagram)
camera control module
camera status processor
status icon
camera focus processor
focus icon
Rang finder icon
send image icon
tcp/ip socket
camera view processor
view icon
image transmission
digital image storage module
camera picture processor
picture icon
optional voice control input

FIG. 9

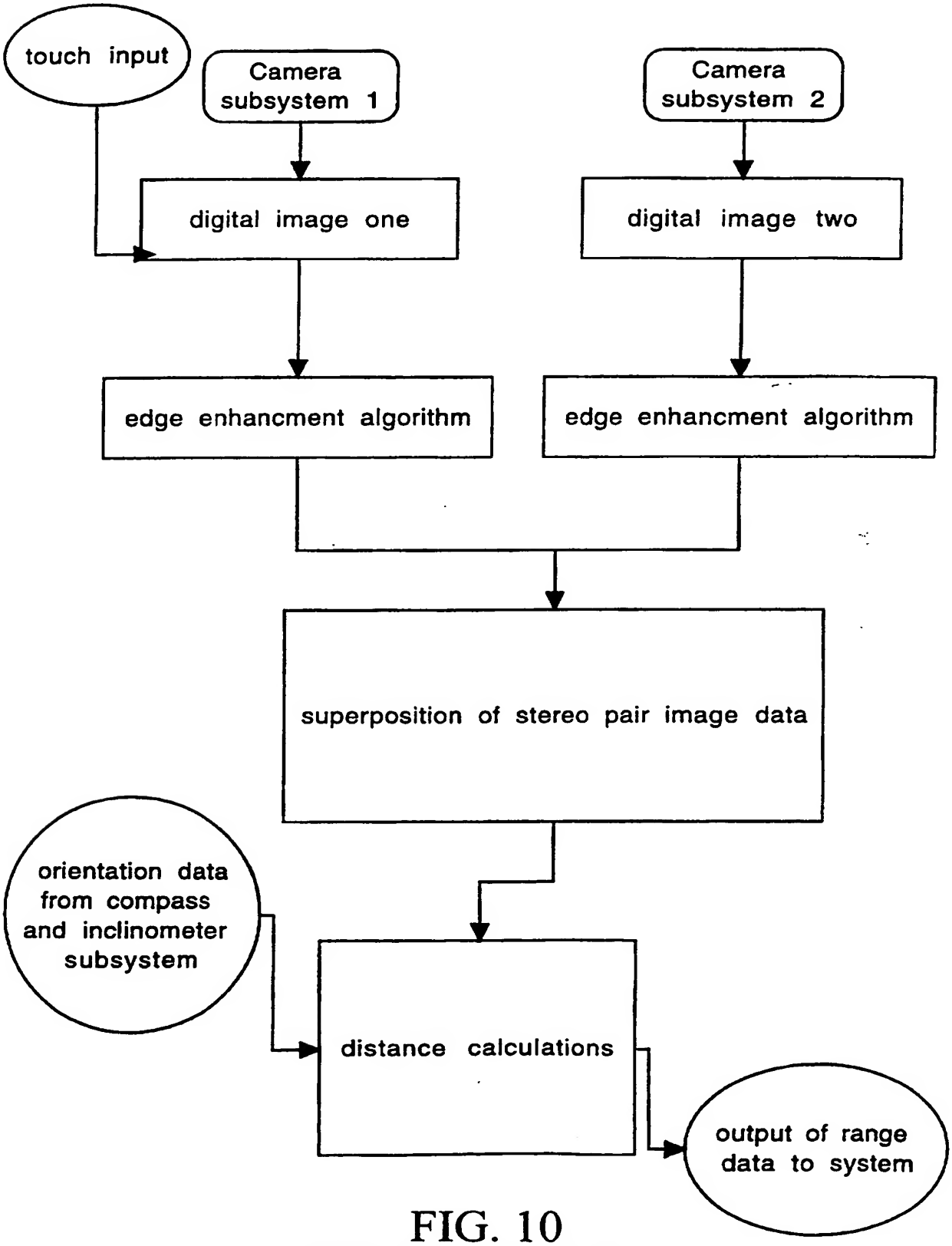

touch input
Camera subsystem 1
Camera subsystem 2
digital image one
digital image two
edge enhancment algorithm
edge enhancment algorithm
superposition of stereo pair image data
orientation data from compass and inclinometer subsystem
distance calculations
output of range data to system

FIG. 10

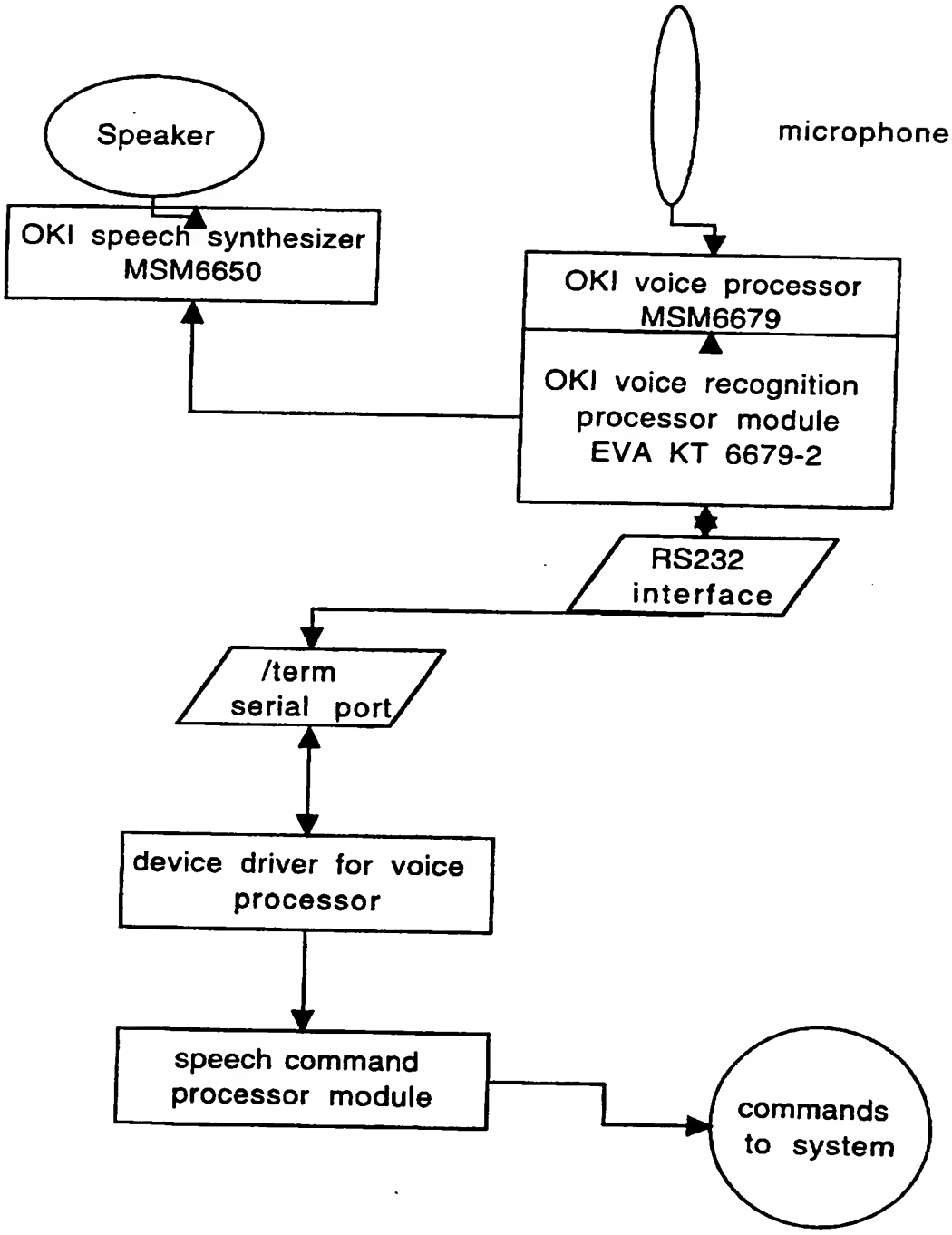

Speaker
microphone
OKI speech synthesizer MSM6650
OKI voice processor MSM6679
OKI voice recognition processor module EVA KT 6679-2
RS232 interface
/term serial port
device driver for voice processor
speech command processor module
commands to system

FIG. 11

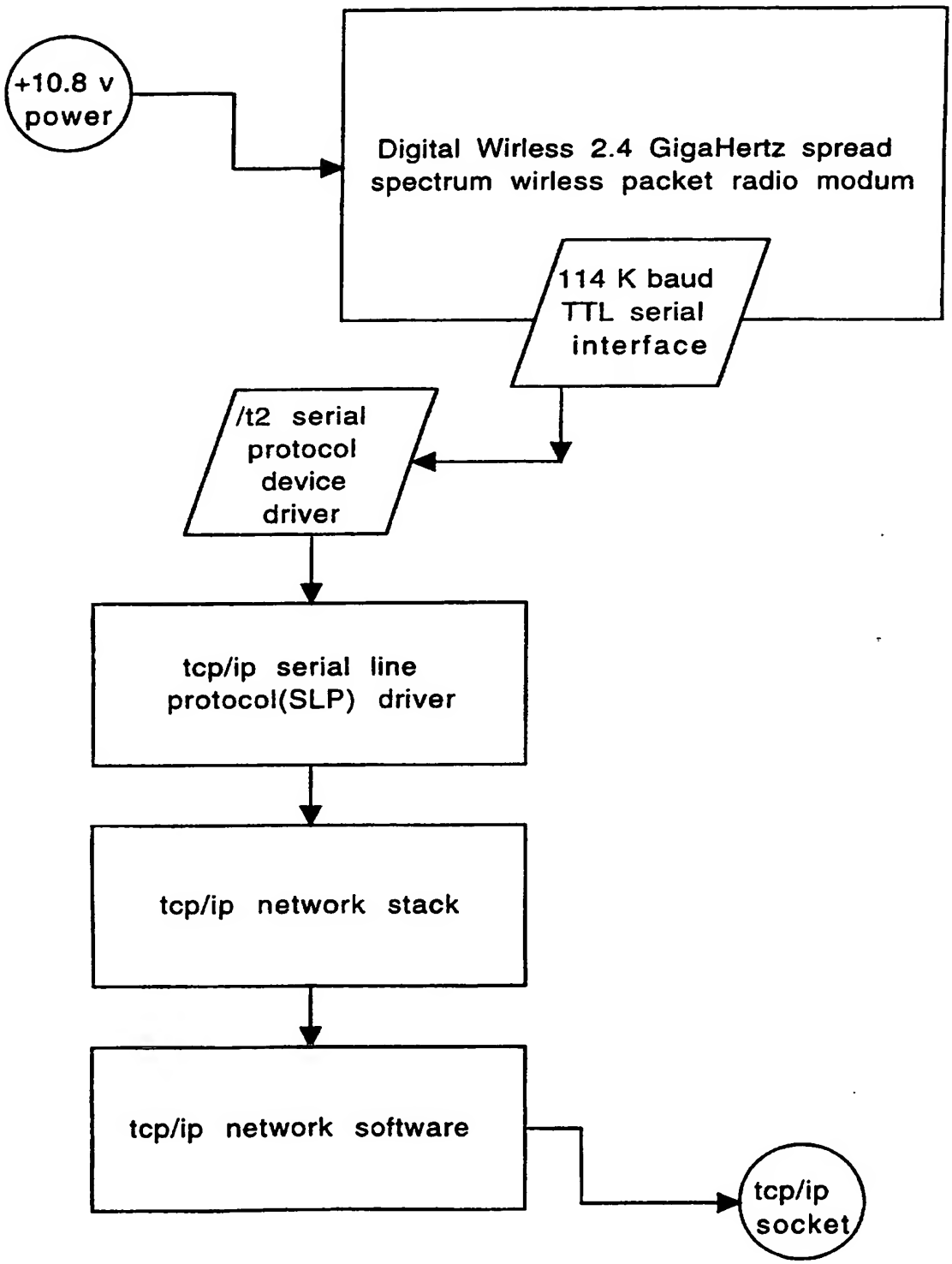
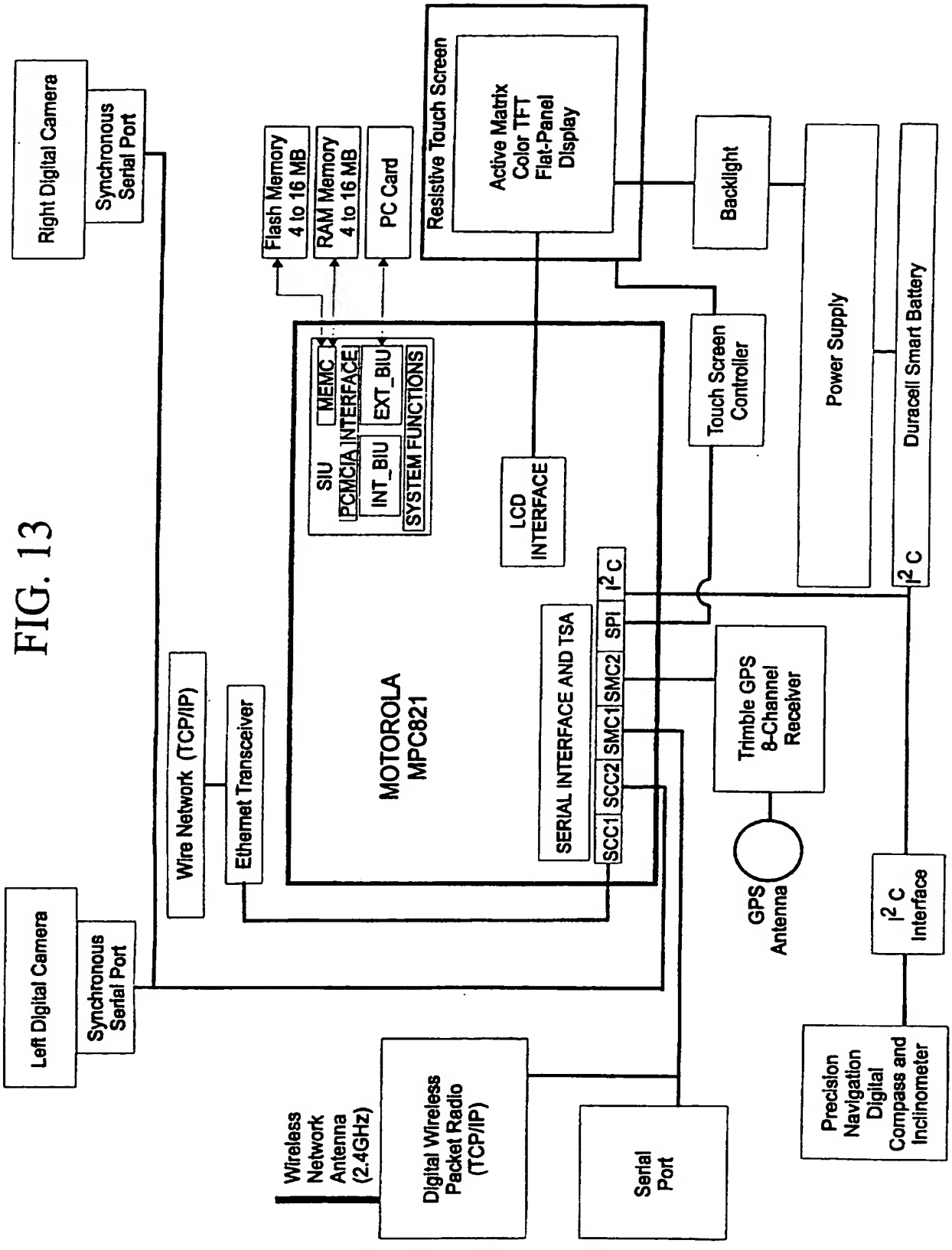

+10.8 v power
Digital Wirless 2.4 GigaHertz spread spectrum wirless packet radio modum
114 K baud TTL serial interface
/t2 serial protocol device driver
tcp/ip serial line protocol(SLP) driver
tcp/ip network stack
tcp/ip network software
tcp/ip socket

FIG. 12

FIG. 13


Right Digital Camera
Synchronous Serial Port
Left Digital Camera
Synchronous Serial Port
Wire Network (TCP/IP)
Ethernet Transceiver
Flash Memory 4 to 16 MB
RAM Memory 4 to 16 MB
PC Card
Resistive Touch Screen
Active Matrix Color TFT Flat-Panel Display
Backlight
Power Supply
Duracell Smart Battery
SIU
MEMC
PCMCIA INTERFACE
EXT_BIU
INT_BIU
SYSTEM FUNCTIONS
LCD INTERFACE
Touch Screen Controller
MOTOROLA MPC821
SERIAL INTERFACE AND TSA
SCC1
SCC2
SMC1
SMC2
SPI
I2C
Trimble GPS 8-Channel Receiver
GPS Antenna
I2C Interface
Precision Navigation Digital Compass and Inclinometer
Wireless Network Antenna (2.4GHz)
Digital Wireless Packet Radio (TCP/IP)
Serial Port

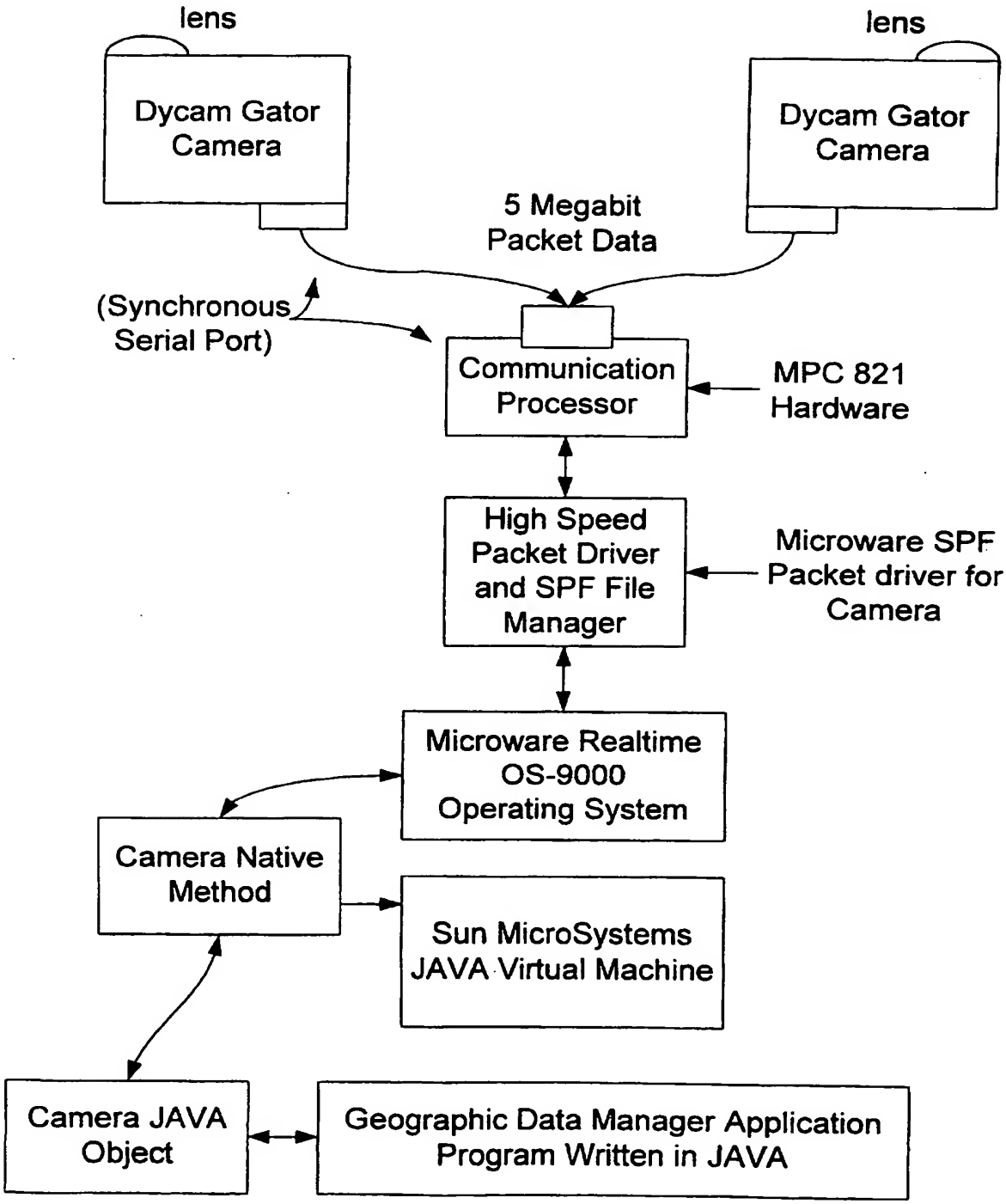

lens
Dycam Gator Camera
lens
Dycam Gator Camera
5 Megabit Packet Data
(Synchronous Serial Port)
Communication Processor
MPC 821 Hardware
High Speed Packet Driver and SPF File Manager
Microware SPF Packet driver for Camera
Microware Realtime OS-9000 Operating System
Camera Native Method
Sun MicroSystems JAVA Virtual Machine
Camera JAVA Object
Geographic Data Manager Application Program Written in JAVA

FIG. 14

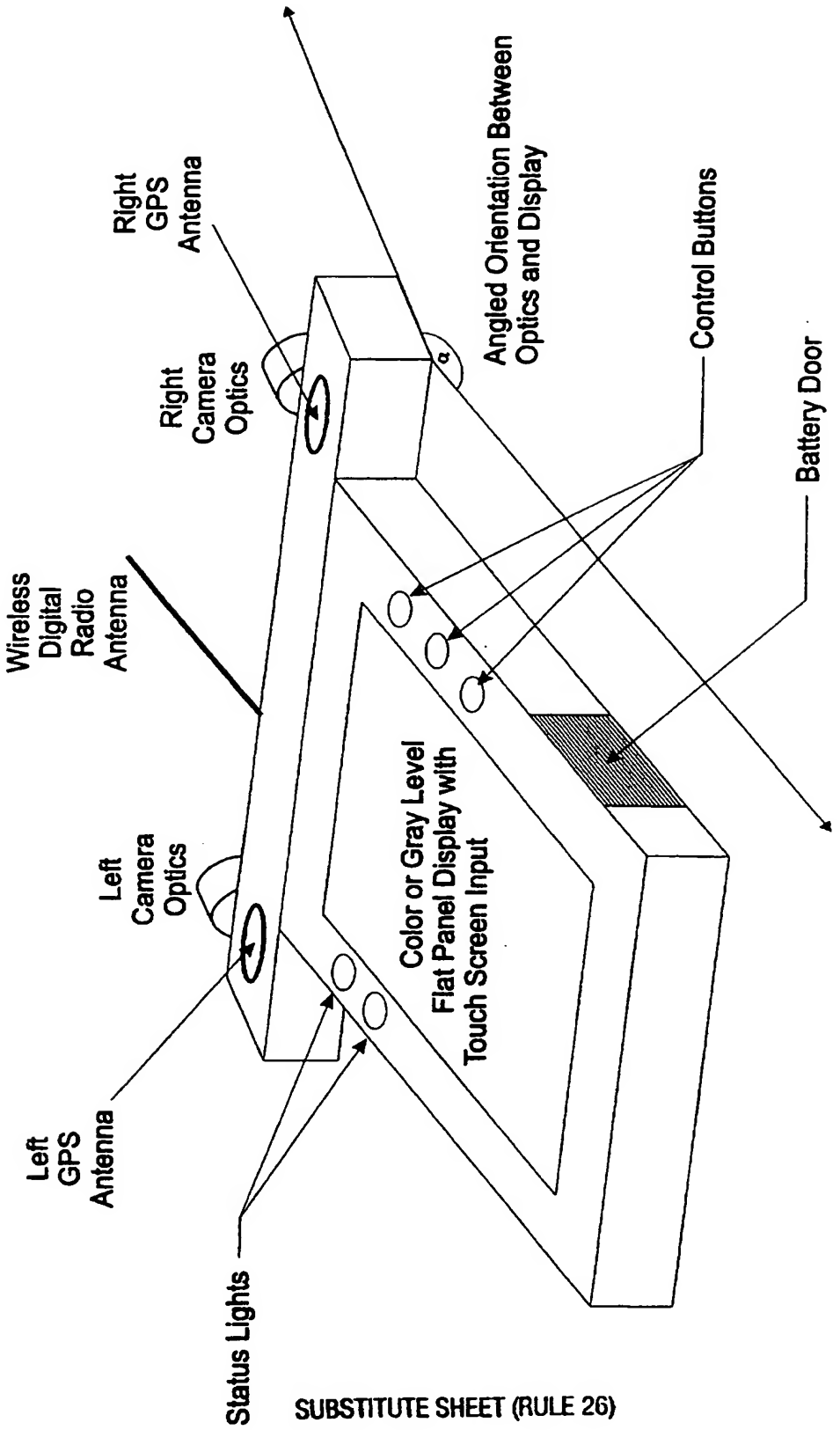

Right GPS Antenna
Right Camera Optics
Angled Orientation Between Optics and Display
Control Buttons
Battery Door
Wireless Digital Radio Antenna
Left Camera Optics
Color or Gray Level Flat Panel Display with Touch Screen Input
Left GPS Antenna
Status Lights

FIG. 15

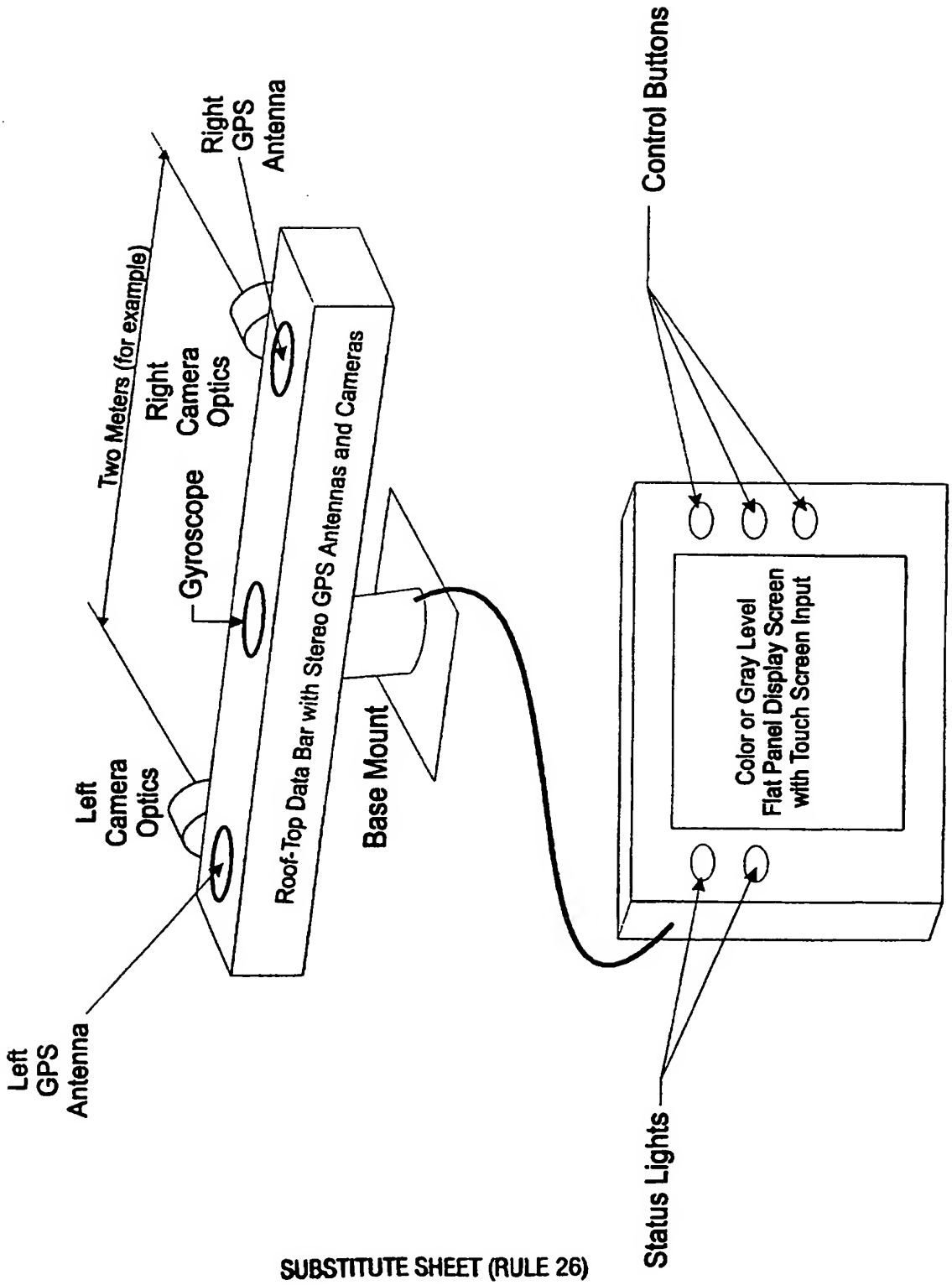

Control Buttons
Right GPS Antenna
Two Meters (for example)
Right Camera Optics
Gyroscope
Roof-Top Data Bar with Stereo GPS Antennas and Cameras
Base Mount
Left Camera Optics
Color or Gray Level Flat Panel Display Screen with Touch Screen Input
Left GPS Antenna
Status Lights

FIG. 16

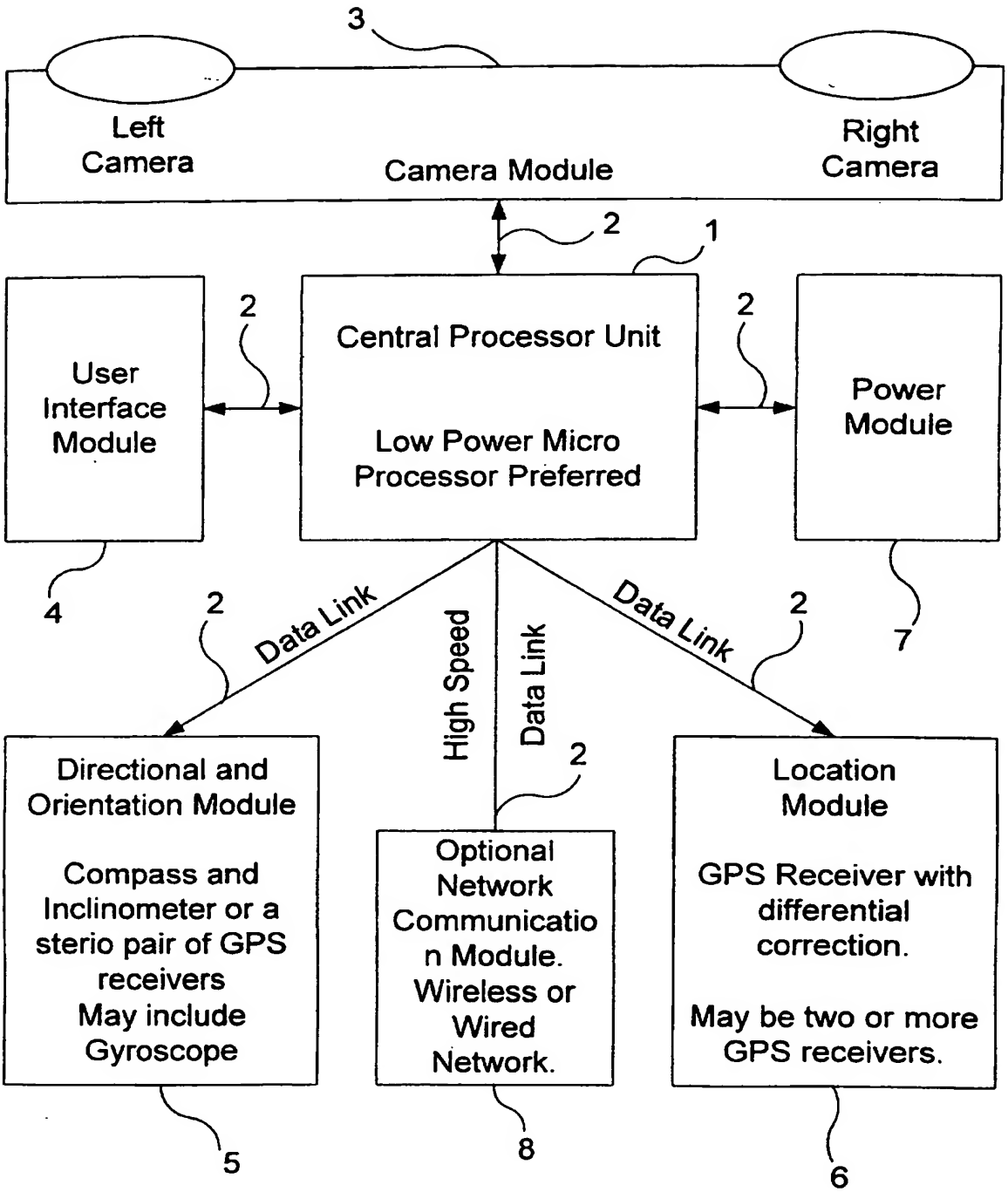

3
Left Camera
Camera Module
Right Camera
2
1
User Interface Module
2
Central Processor Unit
Low Power Micro Processor Preferred
2
Power Module
4
2
Data Link
High Speed
Data Link
2
Data Link
2
7
Directional and Orientation Module
Compass and Inclinometer or a sterio pair of GPS receivers
May include Gyroscope
Optional Network Communicatio n Module. Wireless or Wired Network.
Location Module
GPS Receiver with differential correction.
May be two or more GPS receivers.
5
8
6

FIG. 17

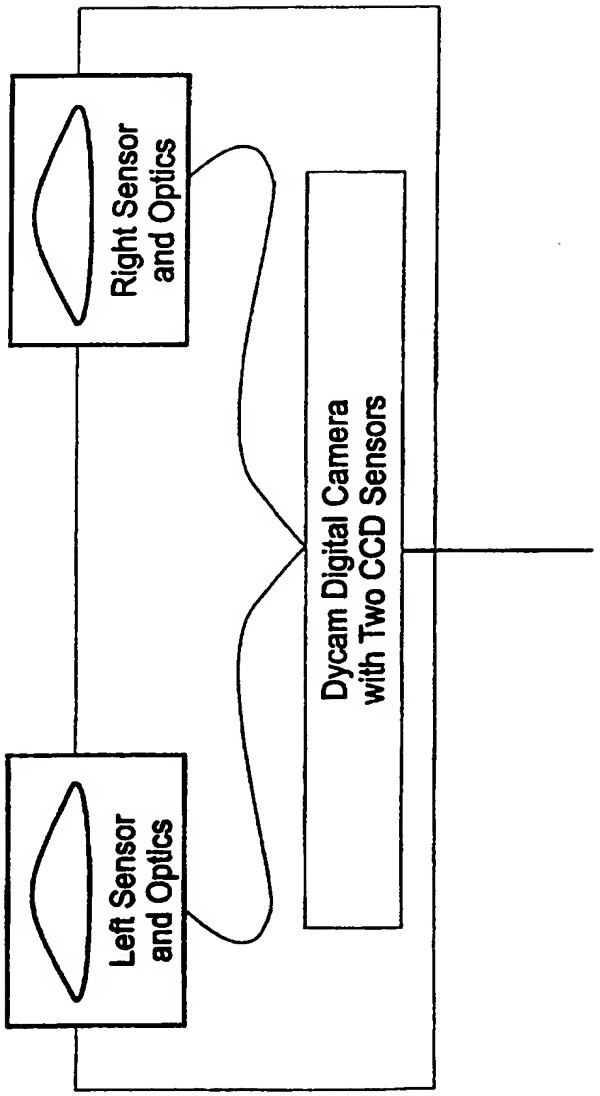

Right Sensor and Optics
Left Sensor and Optics
Dycam Digital Camera with Two CCD Sensors

FIG. 18

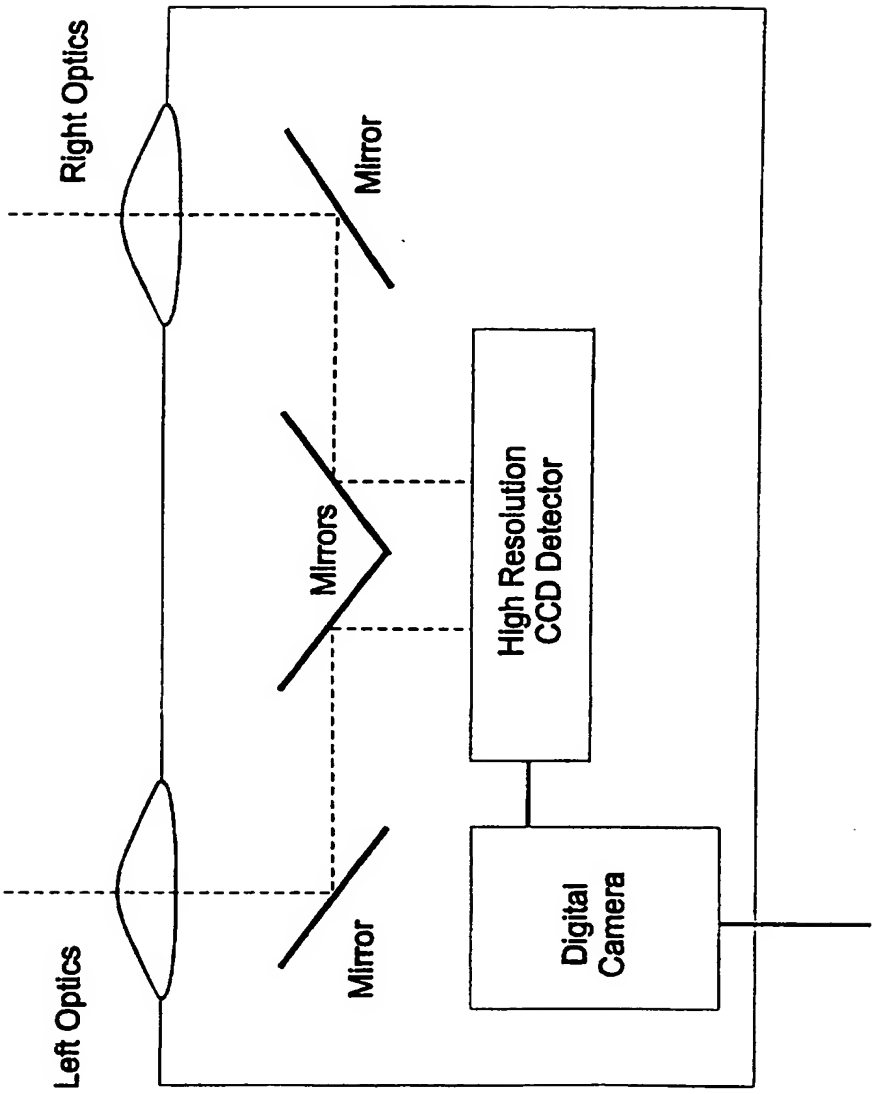

Right Optics
Mirror
Mirrors
High Resolution
CCD Detector
Digital
Camera
Mirror
Left Optics

FIG. 19

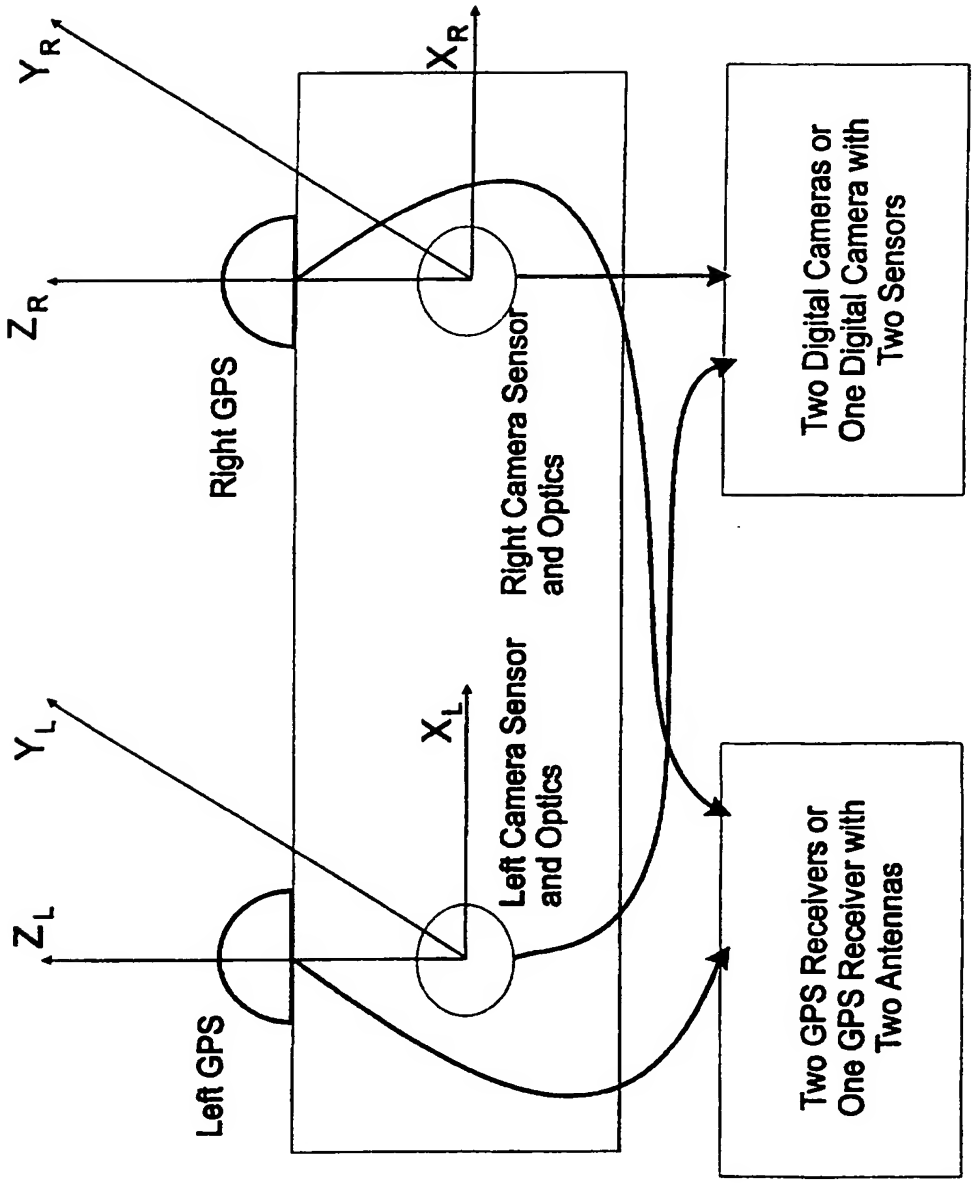

Y_R
X_R
Z_R
Right GPS
Right Camera Sensor and Optics
Two Digital Cameras or One Digital Camera with Two Sensors
Y_L
X_L
Z_L
Left Camera Sensor and Optics
Left GPS
Two GPS Receivers or One GPS Receiver with Two Antennas

FIG. 20

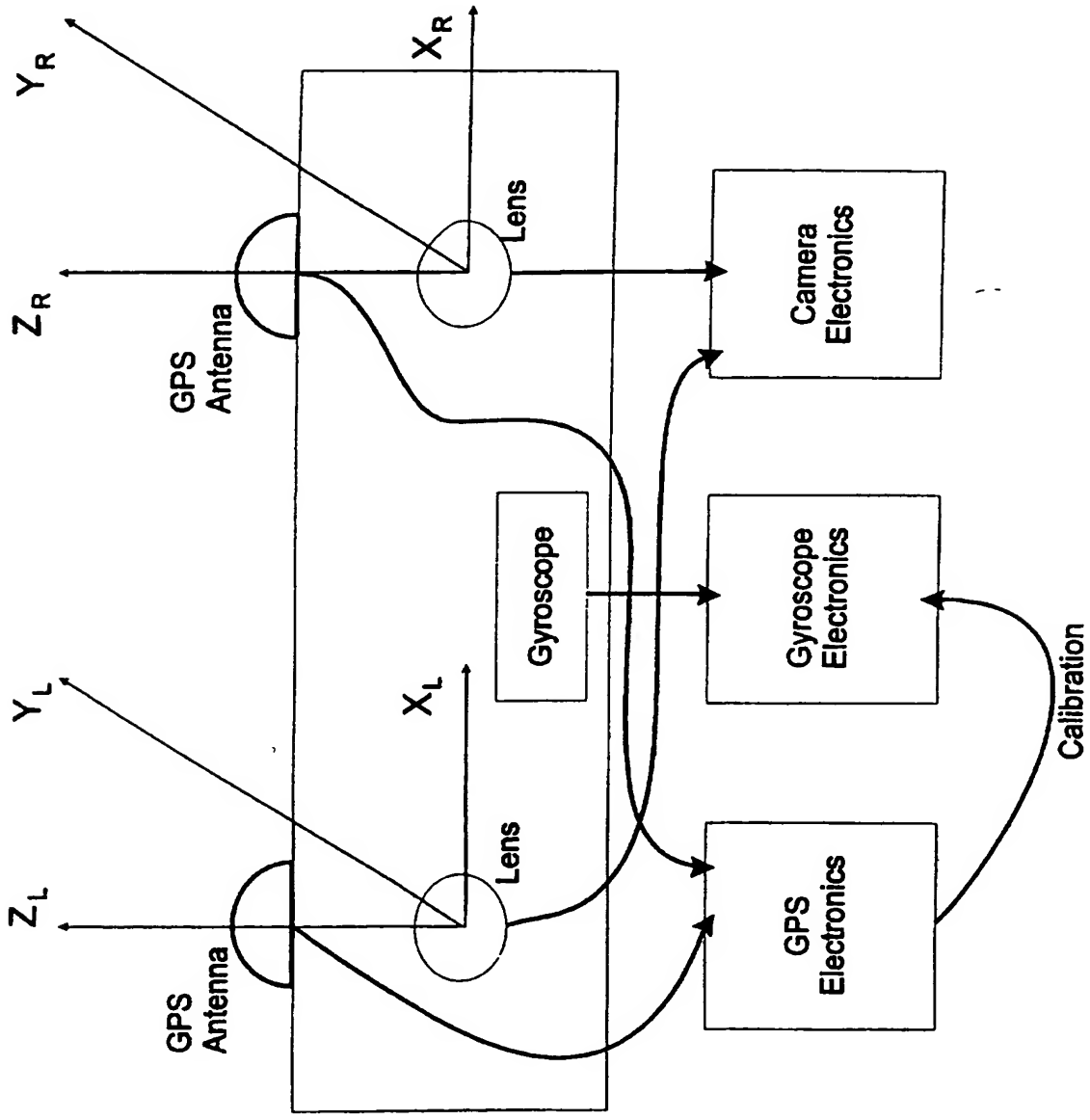

Y_R
X_R
Z_R
Lens
GPS Antenna
Camera Electronics
Gyroscope
Gyroscope Electronics
Y_L
X_L
Z_L
Lens
GPS Antenna
GPS Electronics
Calibration

FIG. 21

INTERNATIONAL SEARCH REPORT

Inte. ional Application No
PCT/US 97/15649

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 G01C11/02

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 G01C

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	PATENT ABSTRACTS OF JAPAN vol. 096, no. 008, 30 August 1996 & JP 08 097927 A (BLUE LINE SHIYA:KK), 12 April 1996, see abstract	1-4, 10-12, 16,17, 19,28, 31,32
X A	WO 95 16895 A (CORE CORP ;MURAI SHUNJI (JP); MATSUMOTO YOSHITAKA (JP)) 22 June 1995 & EP 0 737 845 A (CORE CORP.) 16 October 1996 see the whole document	10-12, 15,16, 22,30 1,4,5,9
A	EP 0 383 114 A (HUGHES AIRCRAFT CO) 22 August 1990 see abstract	1,10

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
5 December 1997	12/12/1997

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Hunt, J

Form PCT/ISA/210 (second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT

Information on patent family members

Int. tional Application No
PCT/US 97/15649

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 9516895 A	22-06-95	JP 7170443 A	04-07-95
		AU 679599 B	03-07-97
		AU 1200095 A	03-07-95
		CA 2179039 A	22-06-95
		EP 0737845 A	16-10-96
EP 0383114 A	22-08-90	US 5060175 A	22-10-91
		DE 69011888 D	06-10-94
		DE 69011888 T	04-05-95
		JP 2523200 B	07-08-96
		JP 3028714 A	06-02-91